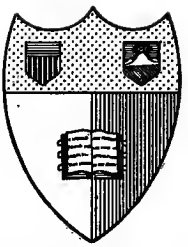

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

EXPLANATION OF SHEETS 330 AND 331 (MAINLAND).

THE GEOLOGY

OF THE COUNTRY NEAR

LYMINGTON AND PORTSMOUTH

BY

H. J. OSBORNE WHITE, F.G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

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187. HUNTINGDON	—	6 0	—
203. REDFORD	—	9 9	—
228. HAVERFORDWEST ...	—	—	3 6
229. CARMARTHEN	1 6	1 6	2 0
230. AMMANFORD	1 6	1 6	2 6
231. MERTHYR TYDFIL ...	1 6	1 6	1 6
232. ABERGAVENNY	1 6	1 6	2 0
248. WEST GOWER	1 6	1 6	0 8
247. SWANSEA	1 6	1 6	2 6
248. PONTYPRIDD	1 8	1 6	1 6
249. NEWPORT (Mon.) ...	1 6	1 6	1 6
264. HENLEY-ON-THAMES ...	—	1 6	2 0
261-2. BRIDGEND	1 6	1 6	1 6
265. CARDIFF	1 6	1 6	2 0
267. HUNGERFORD and NEWBURY	—	1 6	2 6
268 READING	6 9	1 6	1 6
269. WINDSOR	—	—	2 6
282. DEVIZES	—	1 6	1 0
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284. BASINGSTOKE	—	1 6	2 0
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299. WINCHESTER	—	1 6	1 6
300. ALRESFORD	—	1 6	2 0
311. WELLINGTON and CHARD	—	1 6	1 3
314. RINGWOOD	—	1 6	1 0
315. SOUTHAMPTON	—	1 6	1 6
316. HAVANT	—	1 6	1 9
317. CHICHESTER	—	1 6	1 0
325. EXETER	—	1 6	2 0
326 and 340. SIDMOUTH and LYME REGIS ...	—	1 6	1 6
328. DORCHESTER	—	1 6	1 0
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330. NEW FOREST (pts.), I. of WIGHT (pts) ...	7 6	1 6	—
331. PORTSMOUTH and I. OF WIGHT (pt.)	5 3	1 6	—
332. BOGNOR	2 0	1 6	0 6
333. WORTHING and ROTTINGDEAN	—	1 6	—
334. NEWHAVEN and EASTBOURNE	—	1 6	0 6
335. TREVOSE HEAD	—	1 6	2 3
336. CAMELFORD	—	1 6	
337. TAVISTOOK and LAUNCESTON	—	1 6	3 0
338. DARTMOOR	—	1 6	2 3
339. NEWTON ABBOT	—	1 6	3 0
341. WEST FLEET	—	1 6	
342. PORTLAND and WEYMOUTH	—	1 6	10 6
345. SWANAGE	—	1 6	
346. NEWQUAY	—	1 6	3 0
347. BODMIN and ST. AUSTELL	—	1 6	4 0
348. PLYMOUTH and LISKEARD	—	1 6	1 6
349. IVYBRIDGE	—	1 6	3 0
350. TORQUAY	—	1 6	2 0
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PREFACE.

The part of the mainland covered by the New Series one-inch Sheets 330 and 331 is included in the Old Series Sheets 10, 11, 15, 16, and was surveyed by H. W. Bristow, with much help from O. Fisher. These maps were published in 1855-64.

The re-survey on the six-inch scale was carried out by Mr. C. Reid, and was published, in hand-coloured form, on the New Series Sheets 330 and 331 in 1893. These maps, and the Special Map of the Isle of Wight, which covers part of the same ground, were colour-printed in 1903.

The area has furnished classic names to British Geology, such as Barton, Bracklesham, Brockenhurst and Hordle (or Hordwell), but in consequence perhaps of the surpassing claims of the neighbouring Isle of Wight had not been made the subject of any separate memoir, except that some well-sections had been published in the Memoirs dealing with the Water Supply of Hampshire and Sussex. Mr. Osborne White, who had recently completed a Memoir on the adjacent Sheet 316, was fortunately able once more to give his services. In the present volume he has not only summarised what was already known of the local geology, but has contributed many valuable observations made by himself.

We are indebted to the Council of the Geological Society for permission to reproduce Figures 3, 4, 5 and 13 from a paper by Mr. C. J. A. Meyer, and Figures 8 and 9 from a paper by Messrs. Gardner, Keeping and Monckton, published in the Quarterly Journal of that Society.

A. Strahan,
Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.,
26th February, 1915.

(3612). Wt. 38752-73. 500. 6/15. J. T. & S. **G. 14.**

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THE GEOLOGY

OF THE COUNTRY NEAR

LYMINGTON AND PORTSMOUTH.

CHAPTER I.

INTRODUCTION.

Location and Area.—The Lymington and Portsmouth Sheets of the Ordnance Map on the one-inch scale cover the northern half of the Isle of Wight, the Solent and Spithead, and a discontinuous strip of the adjacent mainland (including the islands artificially connected therewith), extending from Milton in Hampshire to East Wittering in Sussex. As the Isle of Wight is the subject of a district-memoir of the Geological Survey, it will receive no more attention here than may appear desirable in order to elucidate the geology of the tract of mainland just indicated.

The western part of this tract, forming what may be termed the Lymington district (Sheet 330), has an area of roughly 90 square miles, in the county of Hants. It includes the southern portion of the New Forest, with Lymington as the only town, and the villages of Hordle, Brockenhurst, Beaulieu, and Fawley. The mouth of Southampton Water, lying just within the limits of the same map-sheet, on the east, constitutes the natural division between this district and that of Portsmouth (Sheet 331). The latter comprises an area of about 50 square miles, of which some 35 belong to Hampshire, and the remainder to Sussex. Besides Portsmouth and Gosport, it takes in Stubbington and Lee-on-Solent,[1] on the west, and South Hayling, West Thorney, and West Itchenor, on the east.

Physical Features.—(1) Land Area. The greater part of the country around Lymington occupies a low plateau, possessing a slight inclination to the south-east, and dissected by the valleys of numerous streams which flow, on the whole, in the same, south-eastward, direction. The highest spot is in the neighbourhood of Clay Hill (215 feet O.D.), a spur of the flat-topped ridge of Wilverley Plain, which divides the upper basin of the Avon Water from that of the Lymington stream. Much of the ground drained by the latter river and its tributary the Ober Water in this part of the district is undulating, sandy bottom-land, covered

[1] The hamlet which formed the nucleus of this new watering-place is marked *Lee* in the current edition (1903) of Sheet 331, which does not show the Lee-on-Solent extension of the Gosport Branch Railway from Fort Brockhurst Station.

by gorse and threaded by gravelly brooks whose courses are marked, here and there, by winding belts of rush and alder.

South and south-eastward, low wooded slopes about Brockenhurst lead gently up to the main mass of the plateau, which, in its northern parts, about Setley Plain, Lady Cross Walk, and Hill-top, east of Beaulieu, presents a succession of wide, nearly-level heaths, diversified by tree-clumps and tumuli, and bordered by friths of oak, fir, and holly. Nearer the Solent the interstream spaces are largely under cultivation. The ground remains as even as before, but the prospects are less wide, and aesthetically much less pleasing; for, with the advent of ordered field and hedge-row, the most characteristic features of the upland landscape of the New Forest disappear, though the quieter stream and woodland scenery of the valleys undergoes little or no deterioration down to the coast.

On the south-west the plateau ends abruptly in the cliffs of Christchurch Bay. These are 115 feet high at Barton, but decline south-eastward with the general slope of the country, and die out near Milford. The cliffs are broken into flights of rough, gravel-strewn steps, due to repeated landslips; they are also notched more or less deeply in places where their recession has caused them to intersect branches of the valley of the Danes Stream, which for part of its course runs parallel with the coast. Along the Solent, from Keyhaven to Southampton Water, the coast is low, and bordered for much of its extent by level tracts of mud which are submerged at high tide.

The local streams are small and may be dismissed in a few words. The more important of them are the Lymington (or Boldre) and Beaulieu (or Exe) Rivers, which are navigable by vessels of low tonnage for a distance of one or two miles above their mouths. These, the Danes Stream, the Avon Water, the Dark Water, and most of the other independent rivulets, occupy valleys of mature form, with flat bottoms and side-slopes of moderate inclination. An exception is met with near Barton, where a branch of the Danes Stream (Sketch Map, fig. 1), recently severed from its trunk and given a short-cut to the sea by the cliff-recession noticed above, has excavated in the former bottom of its valley a ravine, known as Becton Bunny.

Nearly all the older and better-defined villages of the Lymington district lie in the valleys, whereas the later settlements, which are largely residential, are spread out over the intervening high ground, chiefly in the neighbourhood of the coast.

East of Southampton Water, the flat country about Stubbington and Rowner forms a terrace, which is limited by a rise in the ground, above the contour of 50 feet (just outside the area of Sheet 331), on the north, and which presents a low cliff, of 30 feet or less, to the Solent, on the south. The gentle inclination of this terrace south-eastward, down to the coast about Alverstoke and Gosport, is scarcely interrupted, save by the shallow marshy valleys in which the Rivers Meon and Alver pursue their winding courses to the sea at Titchfield Haven and Brown Down.

Throughout the rest of the Portsmouth district—on Portsea Island, Hayling, Thorney, and around West Itchenor and the

Witterings—the ground is almost uniformly flat and low-lying. There are few places where it attains a greater elevation than 23 feet; altitudes of 10 to 20 feet are the rule; and, except in the immediate neighbourhood of the shores and of the partly infilled creeks that run inland along the otherwise indistinct lines of drainage, the slopes are so faint that it is often difficult to perceive their true direction. The most notable feature of this part of the country are the spacious land-locked harbours, which, at high tide, gain much in apparent breadth by the lowness of the surrounding shores. With the ebb, however, they assume a less imposing aspect, for the water, mostly of trifling depth, then withdraws into channels in the harbour-bed, exposing wide stretches of grey mud, partly covered by salt-marsh vegetation.

The bulk of the population of this district is concentrated in and about Portsmouth and Gosport, on either side of the narrow entrance to Portsmouth Harbour. Apart from the modern seaside resorts of South Hayling and Lee-on-Solent, all the other settlements are of small size, and chiefly of an agricultural character.

(2) The Solent and Spithead. The topography of the sea-bed in this strait is of an entirely different type from that of the adjoining mainland. The gently-inclined flats and graded valleys of the country near Lymington and Portsmouth give way off-shore to a multitude of ridges and hollows, the larger of which are elongated in a direction parallel with the coast. On the whole, the submarine relief is moderate. With a few exceptions, such as the 11-fathom colks at the mouths of Portsmouth and Chichester Harbours, depths exceeding 10 fathoms are confined to a chain of troughs which contour the northern shore of the Isle of Wight, and quickly die out in the shallow bottom of the open water to the east and west. Within these hollows the deepest soundings range from about 12 fathoms south of Stone Point, to 17 fathoms in the Spithead channel south of Portsmouth, and 31 fathoms just south of Hurst Castle at the western end of the Solent. The last is the greatest depth charted within the area of Sheets 330-331. It occurs at the foot of a scarp which, from its steepness, has been described as a "submarine cliff."

Geological Formations.—The formations distinguished in those portions of Sheets 330 and 331 with which the present memoir is concerned are as follows:—

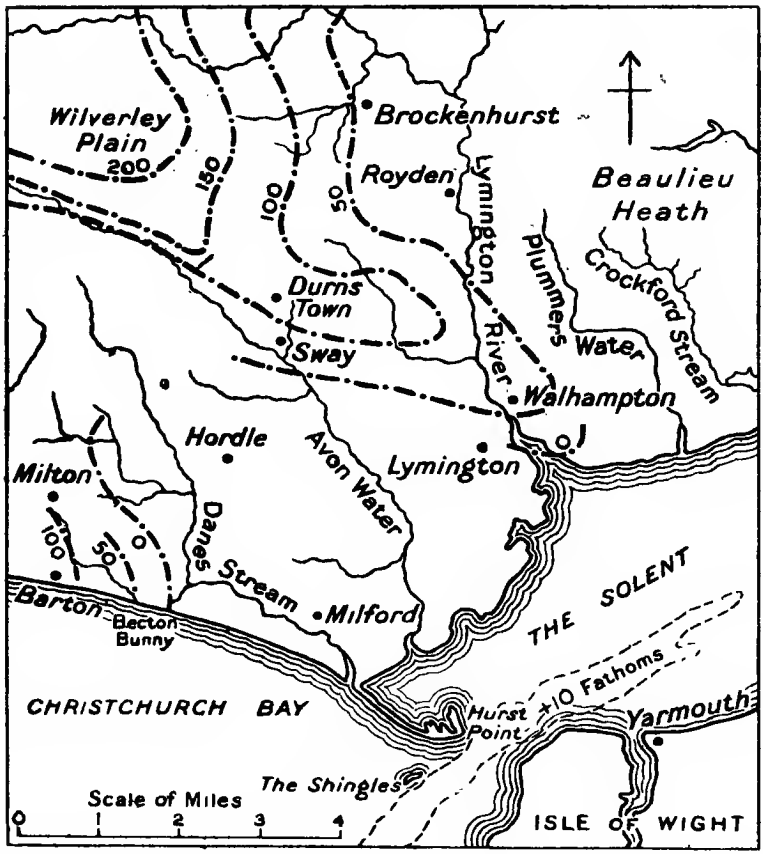
RECENT ...	Blown Sand and Shingle.
	Peat and Alluvium.
PLEISTOCENE	Brickearth.
	Gravel Terraces and Combe Rock.
	Plateau Gravel.
OLIGOCENE...	Headon Beds.
EOCENE ...	Barton Sands.
	Barton Clay.
	Bracklesham Beds.
	Lower Bagshot Beds (Bagshot Sands).
	London Clay.
	Reading Beds.
CRETACEOUS...	Upper Chalk.

Though no local boring has been carried below the Upper

Chalk, the character of the underlying strata, to a depth of about 2,000 feet, may be safely inferred from what is seen in the cliff-sections of the Isle of Wight, in which the descending sequence is continued through the rest of the Chalk, the Selbornian, and the Lower Greensand, down to about the middle of the Wealden Beds; for, beyond some decrease in thickness, the Cretaceous

FIG. 1.—*Sketch Map showing Contours of the Base of the Headon Beds near Lymington.*

Contour-interval 50 feet, from 0 to 200 feet O.D.



system probably undergoes little change between the southern part of the Wight and the coast of the Hampshire mainland. Below the Cretaceous, the Jurassic strata are likely to be, on the whole, as well developed near Portsmouth as in the neighbourhood of their nearest outcrop, in Dorset; but the depth to which they actually extend remains uncertain, while the age of the beds next below them is scarcely less a matter for conjecture. As far as can be judged from data at present available, the Cretaceous Beds are separated by a great thickness of older Secondary

sediments from any rocks likely to contain coal or other minerals of comparable economic importance.

Former Earth-movements.—With regard to the formations which appear at the surface, it may be remarked that those belonging to the Eocene system embody the records of a prolonged movement of subsidence, which affected a wide area of the English region, but perhaps no part more profoundly than that in the neighbourhood of the Hampshire coast. While varying, apparently, from time to time, the rate of this movement did not, on the whole, exceed that at which sediment was accumulating simultaneously in the same area, for, as earlier writers have pointed out, shells indicative of shallow water prevail throughout the 1,500 feet or so of marine strata included in the Eocene of the Hampshire Basin, and at several horizons evidently occupy the positions in which they lived.

The subsidence continued in Oligocene times, and was still in progress when the latest deposits of that period yet surviving in the Isle of Wight (*i.e.*, the Upper Hamstead Beds) were in course of formation. Its rate, however, had become so far diminished that sedimentation was often in excess, and beds of estuarine and fresh-water origin, extending seawards, overspread the marine sediments previously laid down. Though there are reasons to believe that this early Tertiary subsidence was intermittent, there is little evidence of sustained movement in the opposite direction, and assuredly none of an uplift approaching in magnitude that which took place at some epoch subsequent to the formation of the Hamstead Beds.

Concerning local events during the Miocene and Pliocene, very little is known, save that the Oligocene and older strata, besides being elevated as a whole, were deformed by lateral compression (some effects of which will shortly be noticed), and furthermore were subjected to a considerable amount of erosion. No contemporary deposits have been identified on the Hampshire mainland. Certain high-level gravels in the Isle of Wight may date from the Pliocene, but they seem to be older than any of the superficial formations about Lymington and Portsmouth. These latter accumulations imply some oscillation of the land with respect to sea-level in Pleistocene and Recent times, ending in a slight but widespread subsidence, which is thought to have ceased not more than 2,000 years before the beginning of the Christian era.

Tectonic Structure.—The tract of country here dealt with lies in the midst of the Hampshire Basin, a few miles north of the deepest part of that structural depression. Such being its position, it follows that the southern element predominates in the local dips, which, however, are generally low.

In the Portsmouth district the strike of the rocks is determined mainly by the adjacent anticline of Portsdown (Fig. 2, p. 6), whence the strata dips at angles of 2° or 3° in a direction a little west of south. With the failure of that anticline westward, the dip, becoming lower, gradually veers to south-west, and continues with that bearing for a few miles beyond Southampton Water. In the Beaulieu Heath area the beds are almost horizontal, but at a short distance to the west the regional tilt of the

Secondary and Tertiary rocks of the South of England asserts itself over other disturbances, causing the dip to swing round,

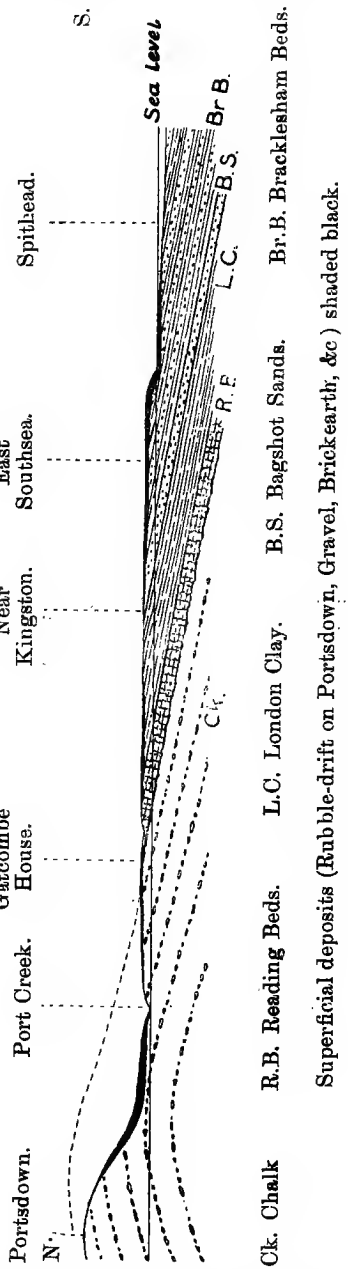


FIG. 2.—*Section through Portsea Island.*

Distance, 7 miles. Vertical scale exaggerated.

Ck. Chalk R.B. Reading Beds. L.C. London Clay. B.S. Bagshot Sands. Br.B. Bracklesham Beds.

Superficial deposits (Rubble-drift on Portsdown, Gravel, Brickearth, &c.) shaded black.

through south, to south-east and east, in the neighbourhood of Lymington and Hordle.

The only minor flexures that call for notice occur in the area of the Lymington Sheet. They form a small group, of which the most distinct member is the gentle anticline running south-eastward through Wilverley Plain, Durns Town, and Walhampton. The curvature is slight, but is clearly brought out by contouring the base of the Headon Beds, as shown in Fig. 1. It is this fold, apparently, which brings up the Osborne Beds at Newtown Bay, on the opposite side of the Solent. In the shallow syncline on its north-eastern flank the Upper Headon, and possibly newer beds of Oligocene age, are preserved, about Royden Farm, north of Boldre. On the south-western side of the anticline there are indications of a downfold running north-westward under Hordle; probably the feeble continuation of the principal syncline of the Isle of Wight.[1]

[1] *See* A. Strahan in 'Geology of the Isle of Wight,' *Mem. Geol. Surv.*, 1889, p. 243.

CHAPTER II.

UPPER CHALK.

Some of the higher beds of this formation emerge from beneath the Eocene strata in the northern part of Portsea, Hayling, and Thorney Islands, and in the country near Bosham east of Thorney Channel. They make little show at the surface, for the ground there is low-lying, and their outcrop is overspread with gravel and loam. Beneath these superficial deposits the Chalk is usually in a weathered condition for a depth of several feet. Besides the local dissolution which results in the formation of "pipes," it has undergone a more general and searching process of decay, which has converted it into a sort of rubble, composed of rounded lumps, more or less hardened by tufa, in a ground-mass of cream-coloured, friable marl.

At West Thorney, about Chidham, and in other places, such chalk was formerly dug for agricultural purposes, but the pits have long since become overgrown, and the few poor exposures now to be seen occur on the shores of the harbours. The clearest of these is presented in the little cliffs on the left bank of Bosham Channel, west-south-west of Southwood Farm, where the Chalk rises in places to about 3 feet above high-water mark. Towards the southern end of the exposure, near the boundary of the Reading Beds, the Chalk is less decayed than usual, and is seen to contain scattered nodules of flint with very thin rinds. Excepting the usual small pieces of *Echinocorys*, *Inoceramus*, and *Ostrea*, fossils seem to be rare, the few observed including—Foraminifera, *Porosphaera pustulosa* Brydone, *Axagaster cretacea* Lonsd., *Bourgueticrinus ellipticus* Miller (cf. form 7 Brydone), *Cyphosoma sp.* (radioles), *Helicodiadema fragile* (Wilts.), *Clausa francqana* (d'Orb.), *Entalophora echinata* (Roem.), *Homoeosolen ramulosus* Lonsd., *Siphoniotyphlus tenuis* (v. Hag.), *Terebratulina striata* Dav., *Spondylus latus* (J. Sow.), and a coprolite.

Though the above are not distinctive, the writer is much disposed to refer this chalk to the upper part of the Zone of *Actinocamax quadratus*.

It is probable that the *Belemintella mucronata* Zone is represented at the outcrop in Portsea and Hayling Islands, as its lower beds occur in Portsdown, a few miles to the north. This zone, however, has not yet been observed in Sussex, and seems not to extend as far eastward even as Bosham Channel.

It is as well, perhaps, to mention that much of the rolled chalk (containing *Marsupites*, *&c.*) on the beaches in the harbours is derived from blocks that have been brought into this district for mending embankments and causeways.

CHAPTER III.

READING BEDS.

As their older names, "Red Clay" and "Plastic Clay," imply, these beds consist in the main of argillaceous sediment. The bright crimson and orange colouration which is so striking a feature of the Reading clays near the surface, in many cases becomes restricted at slight depths to mottlings on a ground of bluish grey, which would thus appear to be the original colour of the beds. Inasmuch, however, as the occurrence of red clays, alternating with the grey or blue, is frequently reported from deep wells, it is probable that the strata composing the Reading Beds varied much in tint from the beginning.

As regards their texture, the clays are, broadly speaking, of two kinds: one of them being stiff, unctuous, and glossy; the other, friable, slightly gritty to the touch, and having a dusty appearance, due to the presence of fine silty matter consisting chiefly of subangular particles of clear quartz. Both sorts of clay often occur in the same bed, the silty kind then forming ill-defined masses or pockets in the truly plastic clay. The same phenomenon is noticeable in the coloured clays of the Wealden formation, and is not easy to explain.

Inconstant beds of pure or loamy sand, occasionally containing seams of incompletely rounded flint-pebbles, occur at various horizons, but are most often met with at the top and bottom of the Reading Series. In the latter position a hard bed, described as "stone" or "rock," has been encountered in some of the well-borings at Portsmouth and Gosport: in another instance, 10 feet of "marl with pebbles" is recorded. Calcareous matter, derived from layers of oyster-shells, or from the underlying Chalk, is usually present in the Bottom-bed in other localities, and has cemented portions of the sand at this horizon into hard stone at Alum Bay, in the Isle of Wight.

Another not uncommon feature of the Reading Beds seems to be referred to in an account of a boring at Gosport Water Works, Bury Cross,[1] where a "brecciated-looking mottled sandy clay, grey, red, and whitish," was traversed, near the middle of the formation. Such breccia-beds, composed of angular pieces of coloured clay in a ground-mass of cross-bedded sand, are attributable to the local and transient scour of the shifting water-currents which played so great a part in the distribution of the early Eocene sediments of this country.

The following extract from the record of a boring made at Milton Asylum,[2] east of Portsmouth, will serve to show the

[1] W. Whitaker, 'Water Suppy of Hampshire,' *Mem. Geol. Surv.*, 1910, p. 93.
[2] *Ibid.*, p. 119.

general character and sequence of the Reading Beds in the district under consideration:—

		Feet.
London Clay [base of], resembling brickearth ...		—
Reading Beds, 98¾ feet.	Light-red clay, with layer of sand 3 to 4 inches thick	6¾
	Black loamy sand	5½
	Dark red clay	2¾
	Grey clay	3½
	Red plastic clay	75¾
	Hard stone	1¾
	Plastic clay and stones	3
Chalk, with occasional bands of flints		—

The total thickness here shown is below the average for the district. Measurements made in other borings range from 98 to 126 feet. The Series thickens southwards, and exceeds 150 feet in the eastern part of the Isle of Wight, the clays still predominating.

No organic remains save lignite, which is seldom seen, are known to occur in the Reading Beds about Portsmouth. It is probable that the Bottom-bed only is marine. The rest of the formation seems to have been deposited under lacustrine conditions of an exceptional kind, to which it is hard to find a close parallel at the present day.

Notes of Exposures.

The southern and northern limits of the belt of ground in which the Reading Beds crop out near Portsmouth can be distinguished in places on the shores of the harbours; the ruddy tint of the mottled clays giving way to the raw sienna of the London Clay on the one hand, and the white or grey of the Chalk on the other. Satisfactory sections, however, are wanting.

The Reading clays were, until lately, much dug for brick-making at Stamshaw, in the northern part of Portsmouth—whence the term "Stamshaw Clay," or simply "Stamshaw," commonly applied to stiff clays by well-sinkers and others in the southern part of Hampshire. The workings there are now closed, and serve as a dumping-ground for rubbish.

In the brick-fields between the high road at North End and the London and South-Western Railway the red and orange clays can be seen in many places where the thin cover of superficial loam has been cleared off; and they are worked to the east of the railway near Great Salterns Farm. On the farther side of Langstone Harbour they reappear in the low cliffs by the Hayling Island Railway near Stoke: they make a vivid streak along the south-western shore of Thorney Island, and of the Chidham peninsula near Cobnor House; but in the slipped ground on the north side of Chichester Channel, near Itchenor Ferry, their brightness is reduced by mottlings of grey.

CHAPTER IV.

LONDON CLAY.

Near Portsmouth the clays, loams, and sands comprised in the London Clay or Bognor Beds have an aggregate thickness of between 300 and 340 feet. Their marine origin is attested by their fossils, which are of warm-temperate facies, and include lamp-shells, shore-crabs, and other forms indicative or suggestive of shallow water.

In this part of the country the Reading Beds seem to have suffered little or no erosion before they were covered by the London Clay; and the lack of well-marked passage-beds between the two formations probably implies no more than that the change from lacustrine to marine conditions was accomplished quickly. It may well have been, for the presence of brackish-water shells in the Reading Beds at Newhaven in Sussex, while it shows that those beds were laid down near the sea-level of the time, also suggests that the effects of the pronounced subsidence which ushered in the London Clay epoch made themselves felt almost simultaneously over a wide area.

Knowledge of the stratigraphy of the London Clay near Portsmouth is mainly due to the researches of the late C. J. A. Meyer,[1] in 1868-70, at the Dockyard Extension Works, between a half and three quarters of a mile south of Whale Island. Meyer's diagrams of the horizontal section exposed in the docks, and the deeper vertical section proved in an adjacent trial-boring, are reproduced as figures 4 and 3, respectively, of the present memoir. These sections jointly cover 242 feet of strata ranging from a horizon 30 feet above the top of the Reading Beds, or "Red Clay," up to a horizon about 10 to 15 feet below the base of the Bagshot Sands.

On comparing the data obtained in the Dockyard excavations with those furnished in accounts of earlier borings in the neighbourhood, Meyer perceived that the London Clay of Portsmouth embodied a "three-fold series of strata," each division of the series beginning with a zone of pebbles and passing upwards, from stiff clays to sandy clays, and sands. This sequence is taken to indicate a progressive shoaling of the sea during the deposition of each division, followed by a relatively rapid increase in depth, due, presumably, to a renewal of subsidence, at the beginning of the next cycle of sedimentation.

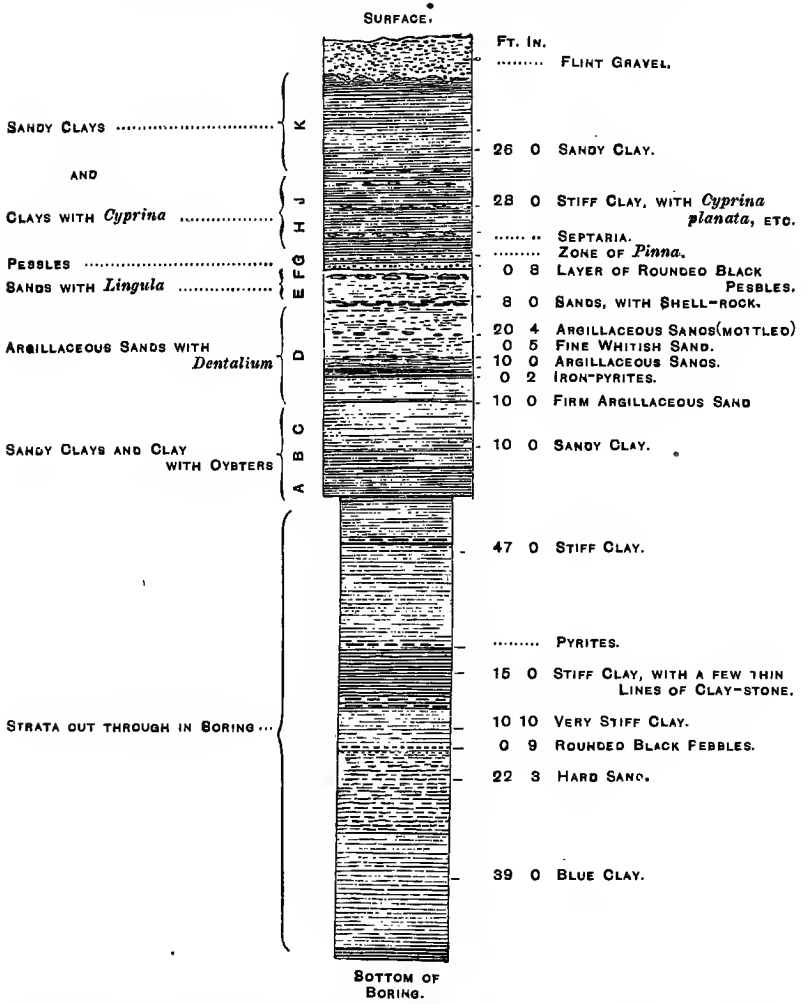
The thicknesses of the three divisions, given in ascending order, are respectively 100, 134, and about 50 to 60 feet. Concerning the lowest, Meyer has little to say, as its characters were known only from records of local borings; and these, though more numerous

[1] 'On the Lower Tertiary Deposits recently exposed at Portsmouth,' *Quart. Journ. Geol. Soc.*, vol. xxvii, 1871, pp. 74-89, 90-92. *See also* C. Evans, 'On the Geology of the Neighbourhood of Portsmouth and Ryde,' *Proc. Geol. Assoc.*, vol. ii, 1873, pp. 61-76, 149-174.

now than when he wrote, still afford no information in regard to a zonal distribution of the fossils, such as Meyer discerned in the middle and upper divisions of the formation. It is known, however, that the lowest division here contains (1) a distinct, though

FIG. 3.—*Vertical section in London Clay, Portsmouth* (C. J. A. Meyer).

(From *Quart. Journ. Geol. Soc.*, vol. xxvii, 1871, opp. p. 80.)



thin, Basement-bed ($\frac{1}{2}$ to 3 feet), composed, as elsewhere, of green sand, calcareous sandstone, flint-pebbles (forming Meyer's lowest "zone of pebbles"), and shells—these last doubtless including *Ditrupa plana* (J. Sow.), which occurs in masses at the same horizon in Whitecliff Bay; and (2), above the Basement-bed,

between 70 and 80 feet of blue clays, with pyrites and septaria, passing up into (3) sand, which is described in some well-records as having a green tint.

The second zone of pebbles, following upon the sand, is the bed mentioned in the third line from the bottom in the subjoined table, which is copied from Meyer's paper.

TABLE SHOWING THE DESCENDING SEQUENCE IN THE LONDON CLAY AT PORTSMOUTH DOCKYARD (*C. J. A. Meyer*).

		ft.	in.	
"Sandy clay [K].	Brownish sandy clay, with thin partings of sand ...	25	0	Zone of *Pleurotoma* (several species).
	Sandy clay	5	4	
	Sand with small nodules of claystone...	0	3	
"Clay with *Cyprina* [J].	Brownish sandy clay	4	0	
	Septaria	0	0	
	Brownish clay	5	9	Zone of *Pectunculus*.
	Septaria	0	0	
	Layer of greasy clay	0	2	
	Stiff greyish clay, with thin partings of sand ...	5	2	Zone of *Aporrhais sowerbii*.
	Sand, with pyrites	0	0½	
	Stiff greyish-brown clay	0	1	
	Septaria	0	0	
	Stiff greyish-brown clay...	5	6	Zone of *Cyprina planata*.
	Sandy clay	0	2	
	Stiff greyish-brown clay...	2	10	Zone of *Pholadomya margaritacea*.
	Thin layer of *Pinna*, crushed and much decomposed. (These shells appear to have been whole when deposited)	0	2	Zone of *Pinna*.
	Thin seam of greasy clay	0	1	
	Stiff greyish-brown clay...	2	1	Zone of *Panopaea*.
"Pebble-bed [H].	Brownish clay, with rounded black flint pebbles ...	0	10	Zone of *Cytherea despecta*.
"Sands with *Lingula* [G, F, E].	Greenish sands, finely bedded and interstratified with thin lines of clay and fragments of carbonaceous matter; fossils numerous	3	0	Zone of *Panopaea intermedia*.
	Layer of greenish chloritous sand, crowded with fossils, and forming the nucleus of a zone of large concretions of shell-rock	0	1	Zone of *Cytherea proxima*, etc., etc.
"Argillaceous Sands with *Dentalium* [D].	Argillaceous sand, slightly mottled	5	0	
	Sand, with double band of Claystone or Septaria, containing thin lines of vegetable matter	1	6	
	Greyish-brown (or greenish-brown) mottled sand, with thin seams of clay	6	0	
	Septaria, at wide intervals	0	0	
	Greenish-grey argillaceous sand, mottled and veined with clay	4	6	Zone of *Pholas*—
	Layer of finely laminated sand, nearly white when dry ... ... (This bed is very constant in thickness within the area of the excavations.)	0	5	
	Greyish argillaceous sands, slightly mottled ...	4	6	Zone of *Cardium laytoni* and *Cytherea suessoniensis*.
"Clays and Sandy Clays with Pyrites [C, B, A].	Septaria	0	0	
	Greyish argillaceous sand, or sandy clay	5	6	
	Thin line of sand, with pyrites...	0	1	
	Thin band of blue clay	0	4	
	Hard sandy clay, with thin lines of stiff clay ...	10	0	
	Ditto, with more clay	5	0	
	Stiff clay	5	0	
	Very stiff clay with large Oysters	18	0	Zone of *Ostrea gigantica*.
"Strata cut through in boring.	Claystone	0	2	
	Very stiff clay	29	0	
	Layer of pyrites	0	1	
	Stiff clay	12	8	
	Claystone	0	2	
	Clay	2	0	
	Claystone	0	2	
	Very stiff clay	10	10	
	Clay, full of rounded black flint pebbles	0	9	
	Hard sand	22	3	
	Blue clay (to bottom of boring)	39	0."	

Passing over the next 55 feet of strata, whose lithological character is sufficiently indicated in the table, we come to the

lowest group of beds exposed in the open excavations at the Dockyard, namely, the—

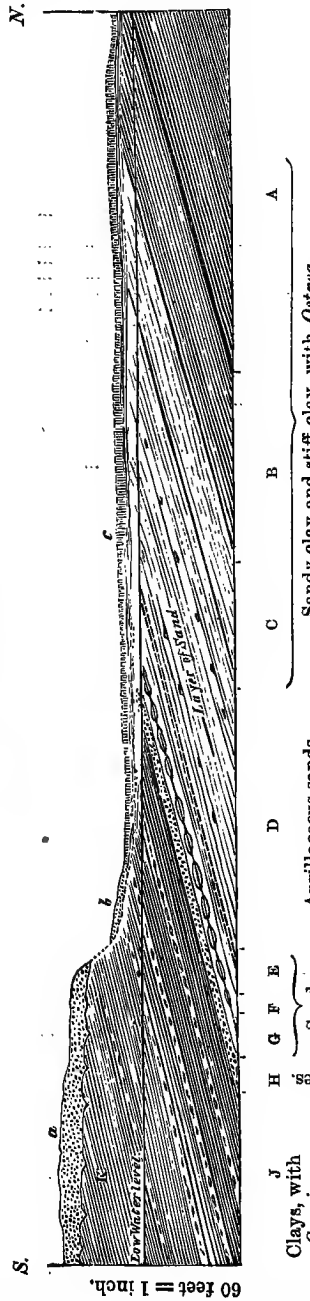


FIG. 4.—*Horizontal section in London Clay, Portsmouth* (C. J. A. Meyer).

Length, 2,000 feet.

(From *Quart. Journ. Geol. Soc.*, vol. xxvii, 1871, p. 75.)

Clays and Sandy Clays with Pyrites (A, B, C, fig. 4).—Fossils are scarce in this division, except in the blue clay (A), which con-

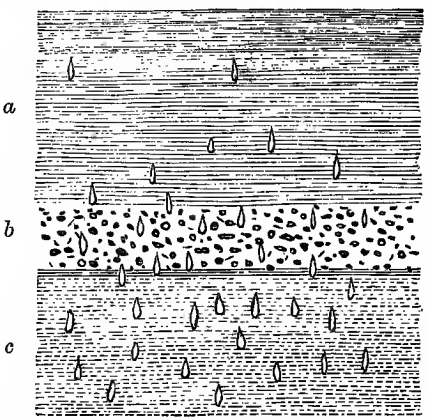
tains *Ostrea gigantica* Sol. (? *O. gigantea* J. Sow.), and masses of drift-wood perforated by *Teredo personata* (Lam.) (*Teredina*).

Argillaceous Sands with Dentalium (D). In this group fossils are fairly common, and dispersed throughout the sands. Meyer records 32 species,[1] of which the following were among those apparently restricted to these beds, the rest ranging higher—a Bryozoon, *Cardium laytoni* Morr. (*Protocardia*), *Cutellus affinis* (J. de C. Sow.), *Cytherea suessoniensis* Wat. (*Meretrix*), *Leda substriata* Morr. (*Nuculana*), *Modiola simplex* J. de C. Sow., *Pholas* aff. *levesquei* Wat. (*Dactylina*), and the crustacea *Litoricola dentata* H. Woodw., *L. glabra* H. Woodw., and *Thenops scyllariformis* Bell.

Sands with Lingula (E, F, G). This group is richly fossiliferous, and yielded upwards of 80 species. A few forms, such as *Lingula tenuis* J. Sow., and *Panopaea intermedia* (J. Sow.) (*Glycimeris*), are abundant throughout, but the greater number were obtained from near the top of the sands (G), where the shells are often worn and drifted together into patches, and from the one-inch layer of sand (F) near the middle, where there are

FIG. 5.—*Section of Pebbly-zone in London Clay, Portsmouth, showing Panopaeae in position* (C. J. A. Meyer).

(From *Quart. Journ. Geol. Soc.*, vol. xxvii, 1871, p. 79.)



a. Stiff Clay (J). *b*. Clay and Pebbles (H). *c*. Sands (G).

concretions of shell-rock which Meyer is disposed to correlate with the Bognor Rock of the Sussex coast. Among the commoner molluscan species noted were *Ostrea flabellula* Lam., *Cytherea proxima* Desh. (*Meretrix*), C. *orbicularis* Desh. [Morris ?] *non* Edw. (*Meretrix*), *Nucula gracilenta* S. V. Wood, *Natica labellata* Lam., *N. subdepressa* Morr. *var.*, *Pyrula smithi* (J. de C. Sow.), *Rostellaria lucida* J. Sow., *Solarium bistriatum* Desh., and *Voluta elevata* J. de C. Sow. Echinoderms were represented by

[1] The reader is referred to Meyer's paper (*op. cit.*), for the full lists of fossils.

Hemiaster bowerbanki Forbes, and crustacea by the crabs *Palaeocorystes glabra* H. Woodw., *Rachiosoma echinata* H. Woodw., *R. bispinosa* H. Woodw., and *Xanthopsis leachi* Bell.

Meyer comments on the apparent mixture, in this group, of London Clay fossils with species more characteristic of the Middle Eocene (Bracklesham Beds), such as *Cardita planicosta* (Lam.) and *Turritella imbricataria* Lam.; and of the Thanet Beds, such as *Cytherea orbicularis* Desh. and *Natica subdepressa* Morris (? *N. infundibulum* Wat.)

The *Pebble-bed* (H)—the third zone of pebbles—makes a change in the conditions of deposition, due "in all probability to a deepening of the sea-bed." Sands give place abruptly to stiff clays, and "of the numerous species of mollusca occurring in the 'Sands with *Lingula*,' many of which abound to within an inch of the zone of pebbles, a few species only reappear at a higher level in the series."[1] In the pebble-bed itself, the most noteworthy fossil observed by Meyer was *Cytherea despecta* Desh. (*Meretrix*), which appeared to be confined to this horizon. The *Panopaeae* range upwards from the "Sands with *Lingula*" to a few feet above the pebbles, "all species occurring with their valves united, and in their natural position (Fig. 5).

In the *Clay with Cyprina* (J) a thin layer of crushed shells of *Pinna affinis* J. Sow., occurs about 2 feet above the pebble-bed. Other fossils recorded include *Cyprina planata* J. Sow. (*Arctica scutellaria* (Lam.)), *Pectunculus brevirostris* J. de C. Sow. (*Axinaea*), *Pholadomya margaritacea* J. Sow., *Turritella sulcifera* Desh., *Nautilus imperialis* J. Sow.

From the *Sandy Clay* (K), which is close to the junction with the Bagshot Sands, Meyer mentions *Aporrhais sowerbyi* (*Mant.*), *Rostellaria lucida* J. Sow., *Chrysodomus sp.*, and several species of *Pleurotoma*, including *P. stena* Edw., and *P. teretrium* Edw. This was the highest bed exposed in the Dockyard section.

Reverting to the so-called "zones of pebbles," it may be remarked that those which occur at horizons respectively 100 and 234 feet above the base of the London Clay appear to be fairly persistent about Portsmouth and Gosport. Farther afield, the lower of these may be represented by the similar band, 70 feet above the Reading Beds, at Alum Bay; while the upper pebble-bed has been recognised both at Whitecliff Bay and in the Catisfield cutting on the Netley Branch Railway, near Fareham. Mr. J. W. Elwes showed that certain beds exposed in the Catisfield cutting could be correlated in detail with those distinguished by the letters G, H, J in the section at Portsmouth Dockyard.[2]

But it must not be inferred from the foregoing remarks that the pebbly episodes in the London Clay are restricted to the three horizons so far indicated. Others appear, in different positions, not far west of Portsmouth. Thus, in a well at Stubbington,

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[1] Meyer, *op. cit.*, p. 79.

[2] J. W. Elwes, 'Sections opened on the New Railway from Fareham to Netley,' *Pap. and Proc. Hamps. Field Club*, No. ii. 1888, pp. 31-39. *Also* H. J. O. White, 'Country near Fareham, etc.', *Mem. Geol. Surv.*, 1913, pp. 47-52.

three pebble-beds were encountered within 103 feet of the base of the Bagshot Sands; a Southampton well-boring proved four within 84 feet of that datum, and another boring in the same town traversed six or seven such beds between the upper and lower limits of the London Clay.[1]

Notes of Exposures.

The only sections having any degree of permanence are those presented in the banks of the harbours; and in such places the beds are almost always much altered by weathering. The western side of Portsmouth Harbour north of Elson, Longmere Point south of West Thorney, and the bluffs east of Chichester Channel near West Wittering, may be mentioned as places where clays and loams with septaria are fairly well displayed. West of Longmere Point, where the beds have suffered less than is usual from weathering, the low cliff and foreshore reefs give good exposures of blue shaly clay in the lower part of the formation. The clay contains much tabular cement-stone (often septarian), pyrites, and pyritised wood. Near the junction with the overlying gravel there is a notable development of "race," in nodules possessing a reticulate structure.

In 1891 Mr. Clement Reid saw blue clay, containing *Cytherea suessoniensis* Wat. (*Meretrix*) and abundant *Turritella imbricataria* Lam., in material from a well in the upper part of the London Clay at the brickyard north of the church at Elson, near Gosport; also green sand and pebbles from the Basement-bed, in similar circumstances, at the southern end of Fleet, on Hayling Island.

Loose blocks and flags of light-brown calcareous and ferruginous sandstone ("Bognor Rock"), often containing *Vermicularia bognoriensis* (Mant.), *Axinaea brevirostris* (J. de C. Sow.), and, occasionally, *Glycimeris intermedia* (J. Sow.), and *Pinna*, are to be seen in many places east of Portsmouth; on the coast, on the shores of the harbours, and inland. Probably the "Sands with *Lingula*," described above, are not the only source of this material, though they may be the chief one. Pieces of the rock are plentiful on the shore half a mile south-west of Fleet on Hayling Island, and at the southern end of Thorney. Some fresh-looking blocks, possibly taken directly from the London Clay, can be seen in a rockery at the entrance to the Dust Destructor at Copnor.

[1] *See* 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, pp. 127, 128, 131, 140.

CHAPTER V.

BAGSHOT SANDS.

The poorly fossiliferous sandy clays and loamy sands which, in alternating layers, form the highest part of the London Clay, pass upwards into more purely arenaceous strata, for which no satisfactory name has yet been found. The term "Bagshot Sands" is here preferred to the "Lower Bagshot Beds" of the legends to Sheets 330 and 331 of the Geological Survey Map, and to the alternative "Alum Bay Sands," not because it is less open to objection, but for the reason that it is the term employed in the published Sheet-memoirs relating to adjacent districts.

About 100 feet thick in the Isle of Wight, these sands thin away northward and north-eastward to 30 feet, or less,[1] at their outcrop on the mainland near Spithead; and in the level, drift-mantled country east and west of Portsmouth they are so little in evidence at the surface that their existence might easily be overlooked.

Local borings indicate the presence of pebble-beds—mostly of small thickness—and of pyrites-nodules and lignite. The pipe-clays of Corfe and Alum Bay are but feebly represented, and are not known to have yielded any relics of sub-tropical plants, such as occur in those localities.

The Bagshot Sands are closely related to the beds below them, but they evidently mark a more pronounced shoaling of the early Eocene (Cuisian) sea than any recorded in the recurrent sandy episodes within the London Clay. It is doubtful whether they are wholly marine near Portsmouth, or embody extensions of some of the freshwater beds seen to the west. In the country north and north-west of Portsmouth the Sands include masses of wave-worn shingle, which indicate the vicinity of contemporary sea-beaches.

Notes of Exposures.

The few openings observed by the Officers of the Geological Survey during the past fifty years have nearly all disappeared.

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[1] The thickness assigned to these beds in the records of Gosport and Portsmouth well-borings, published in the memoir on the 'Water Supply of Hampshire' (1910), varies from 17 to 39 feet, but some doubt attaches to the figures much above and below 30 feet.

The correctness of the stratigraphical interpretations there placed upon certain records is admittedly open to question. Having regard to the trend of the outcrops, and the character of the strata proved in neighbouring wells, the beds traversed in the boring at Messrs. Curtis's (p. 115) are less likely to belong to the Bracklesham and Bagshot Beds, to which they are assigned, than to the London Clay and Reading Beds. It is improbable, too, that the Bagshot Sands occur so far north as Kingston Brewery (*loc. cit.*), close to Kingston Crescent; the more so in that the Chalk was reached at a depth of only 210 feet from the surface in a well at the adjacent Lion Brewery (p. 118).

H. W. Bristow mentions a pit in white and yellow sand, with thin seams of white pipe-clay, near the shore between Elson Hardway and Priddy's Hard. Fine, light-coloured sand was noted by Mr. W. Whitaker in a brickyard (since built-over) a quarter of a mile north of Fratton Station, and in a pit near the Lunatic Asylum at Milton. The 2½ feet of "ordinary gravel," encountered beneath 29 feet of white running sand in the upper part of a well at the Asylum,[1] may be one of the impersistent pebble-beds so common in the Bagshot Sands.

East of Portsea Island this formation is not marked on the map, but part, at least, of the sandy beds, between the hard blue clays referred to the London Clay and Bracklesham Beds, in the record of a well made near South Hayling Station, may belong to it; and the same can be said of the loamy sand with flint-pebbles exposed in the bank of Chichester Harbour by West Wittering Coastguard Station.

[1] 'Water Supply of Hampshire,' 1910, p. 119.

CHAPTER VI.

BRACKLESHAM BEDS.

This formation consists of dark green and blue glauconitic sandy clays with much selenite and marcasite, alternating with light-coloured sands and laminated carbonaceous loams with frequent seams of lignite; the total thickness being about 600 feet, in the eastern part of the Isle of Wight. Marine shells of sub-tropical aspect occur freely in many of the more argillaceous beds, and at some horizons are massed so as to form layers of shelly marl. In the sandy beds shells are usually wanting, or represented by scattered casts in iron oxide; while the lignitic loams seldom afford indications of animal life. A sandy clay in which well-rounded flint-pebbles are dispersed in one or two uneven bands about a foot thick, occurs with much persistence at the base of the Bracklesham Series, and other pebbly bands, usually less distinct, are met with at higher horizons.

The outcrop dealt with in this memoir extends from near the head of Bracklesham Bay, on the east, to Brownwich at the mouth of Southampton Water on the west, and is all but comprised in the area of the Portsmouth Sheet (331) of the one-inch map. The principal exposures have been described in earlier works, of which the most important is a paper by the Rev. Osmond Fisher, published in 1862.[1]

Mr. Fisher divides the Bracklesham Series into four groups (lettered A to D), each containing one or more beds rich in fossils.

The highest group, A, generally abounds in Gasteropods, and one (at least) of its fossil-beds is full of *Nummulites variolarius* (Lam.).

Group B, more sandy than the last, also contains *N. variolarius* in its principal shell-bed, and is marked by the presence of *Cerithium giganteum* Lam. (*Campanile*).

These two groups comprise what is now known as the Upper Bracklesham (Auversian).

Group C, also sandy, is characterised by an abundance of *Nummulites laevigatus* Brug., and

Group D, mostly less fossiliferous than the higher groups, is distinguished by the occurrence of *Cypraea tuberculosa* Duclos, and *Cardita acuticosta* ? (Lam.).

The latter two groups form the Lower Bracklesham (Lutetian).

Mr. Fisher takes as his standard the admirable section in the cliffs of Whitecliff Bay, and as this lies within 14 miles of all the mainland exposures of the Bracklesham Beds in the Portsmouth district, and will, moreover, be referred to often in the present chapter, a summary of its leading features is given on the next page. Mr. Fisher's grouping and numeration of the beds is here retained, but some of the details given in his table are excised for the sake of brevity, and others are altered where emendation has become necessary as a result of more recent researches. The place-names and other appellations by which the most fossiliferous beds are known to collectors are inserted in parentheses.

[1] 'On the Bracklesham Beds of the Isle of Wight Basin,' *Quart. Journ. Geol. Soc.*, vol. xviii, 1862, pp. 65-93.

SECTION OF THE BRACKLESHAM BEDS AT WHITECLIFF BAY, ISLE OF WIGHT.

			Ft.
		Barton Beds.—Green and blue clays with Zone of *Nummulites elegans* (1 ft.) at base	—
Upper Bracklesham Beds.	A, 184 ft.	XIX.—('Huntingbridge Beds,' lower part of). Greenish and blue clays[1]	94
		XVIII.—Dark blue and green sandy clay	22
		XVII.—('*Nummulites variolarius* Zone.'). Blue clay crowded with *N. variolarius* (Lam.), also *Alveolina sabulosa* (Montf.), *Turbinolia sulcata* Lam., *Orbitulifera petiolus* (Lonsd.), *Fusus longaevus* (Sol.) (*Clavalithes*), *Pleurotoma denticula* Bast., *&c.*	10
		XVI.—('*Tellina* Bed.'). Light-coloured sand and sandstone with *Tellina donacialis* Lam., *T. plagia* Edw.	6
		XV.—Sandy clay, passing into lead-coloured clay with *Ancillaria canalifera* Lam.	10
		XIV.—('Brook Bed.). Dark sandy clay, full of *Corbula pisum* J. Sow. above, and *Pecten corneus* J. Sow. (*Pseud-amusium*) below. *Nummulites variolarius* (Lam.), *Cytherea lucida* J. de C. Sow., *Voluta nodosa* J. de C. Sow., *&c.*	
		XIII.—Dark-green clay and sand with *Pecten corneus* J. Sow., passing into light-coloured loamy sands[2] (footnote next page)	39+
	B, 27 ft.	XII.—Sands, white and yellow	10
		XI.—Sandy clays with *Sanguinolaria hollowaysi* J. Sow. (*Gari* ?), *Pecten corneus* J. Sow., *Pectunculus pulvinatus* Lam. (*Axinaea*)	4
		X.—Sand, yellow and grey	7
		IX.—('*Cerithium giganteum* Bed.'). Brown sandy clay with scattered pebbles. *Numm. variolarius* (Lam.), *Cerithium giganteum* Lam. (*Campanile*), *Turritella sulcifera* Desh., *Murex minax* Sol.	6
Lower Bracklesham Beds.	C, 123 ft.	VIII.—Laminated sandy clays with lignitic seams in upper part, and fossiliferous band with *Nummulites laevigatus* Brug., *&c.*, near the middle[3] (footnote next page)	46
		VII.—('*Nummulites laevigatus* Bed.'). Green sand with *Sanguinolaria hollowaysi* J. Sow. Mass of *N. laevigatus* Brug. 4 ft. above base	15
		VI.—Green sands with *Nummulites laevigatus* Brug., *Cardita planicosta* (Lam.), *Natica labellata* Lam., *Turritella sulcata* Lam., *T. sulcifera* Desh.	62
	D, 251 ft.	V.—Laminated grey clay with seams of lignite and a bed (4–6 ft.) of brown coal[4] (footnote next page)	76
		IV.—('*Cardita* Bed.'). Calcareous loamy sand with *Nummulites laevigatus* Brug., *Ostrea flabellula* Lam., *Cardita planicosta* (Lam.), *Cytherea suberycinoides* Desh. (*Meretrix*), *Turritella imbricataria* Lam.	52
		III.—Green sand and laminated clays with seams of lignite	18
		II.—Sand, yellow	10
		I.—Laminated sandy clay and green sand. Casts of shells (*Cytherea* ?, *Tellina* ?) in clay just above pebble-bed (1–1½ ft.) at base ...	95
		Bagshot Sands, yellow	—
			596

[1] Fisher (*op. cit.*, p. 70) makes this division (XIX) 162 feet thick, as he includes in it 68 feet of clays now referred to the Barton Beds. H. Keeping states (*Geol.*

The Upper Bracklesham is wholly marine at Whitecliff Bay, and maintains this character throughout its visible extent in the Hampshire Basin, except at Alum Bay, where marine fossils are confined to about 40 feet of beds (apparently the equivalent of Division XIX) immediately below the Zone of *Nummulites elegans*. Its fauna is distinguished from that of the Lower Bracklesham by the presence of a number of molluscan species which range up into, and in many cases attain their fullest development in, the Barton Beds. The Lower Bracklesham was formed under more variable conditions. At Whitecliff Bay the glauconitic beds with marine shells alternate with beds containing no organic remains except lignite. Though much of the lignite seems to have been formed from drifted vegetable-matter, it is clear, from the presence of root-beds or "underclays" in Divisions V and VIII, that part of it represents plant-life that flourished on the spot—presumably in swamps[5] near sea-level.

In the Selsey peninsula, to the north-east, the Lower Bracklesham seems to be entirely marine, but the exposure there is by no means complete. At Gosport, to the north-west, the marine shell-beds with *Nummulites laevigatus* in the higher part of the Lower Bracklesham are thinner than at Whitecliff Bay, and the underlying laminated beds with lignite are proportionately expanded. At Alum Bay marine beds of this age have not been recognised; probably they are replaced, together with much of the Upper Bracklesham, by the barren sands and clays which are doubtfully classed as Lower Bagshot Beds in the Geological Survey Memoir in the Isle of Wight[6]; and when seen again, at Bournemouth, they are intercalated in beds of freshwater origin, amid which they dwindle westward and disappear.

Notes of Exposures.

It will be convenient to notice these under three geographical headings, namely (1) Bracklesham Bay, (2) Hayling and Portsea Islands, and Spithead, (3) Gosport and Lee-on-Solent.

1. *Bracklesham Bay.*—As the general section here is already

Mag., 1887, p. 72) that the *Nummulites elegans* Zone is 126 feet distant from the '*Tellina* Bed' (XVI), and measurements made recently by the writer of the present memoir agree with this, to within a foot or two. It should be noted that the sum of the measurements given by Keeping (*ibid.*, p. 71), and by Gardner, Keeping, and Monckton (*Quart. Journ. Geol. Soc.*, vol xliv, 1888, p. 604) is only 90 feet 7 inches.

[2] Described by Fisher,—"Beds not exposed, apparently clays, 39 feet." The upper 12 feet naturally belongs to division XIV, above; and the thickness appears to be about 50 feet.

[3] Fisher mentions no fossils from this division. Attention has lately been called to the existence of the fossiliferous bed near the middle by J. Boussac (*C. R. Acad. Sci., Paris*, cxlv, 1907, p. 361).

[4] The bed of brown coal in this division can be none other than that noticed in the Geological Survey Memoir on the Isle of Wight, 2nd ed., 1889, pp. 113, 114, though it is there assigned to a higher horizon—apparently division VIII.

[5] The structure of the 'underclay' of the brown coal (V) at Whitecliff strongly suggests that that bed was in a pasty condition when the roots were intruded.

[6] pp. 101, 116.

well known from the writings of Dixon,[1] Fisher,[2] Reid,[3] and other authors, only a brief account of it will be given in the present work.

Sheet 331 includes the stretch of shore, about 3½ miles in length, which lies between the mouth of Chichester Harbour and Bracklesham Farm. The face of the low cliff of Bracklesham Beds and superficial deposits is largely hidden by banks of shingle, and what little there is to be seen of the solid strata is in a weathered condition. The low reefs which emerge here and there from the broad flats of sand between tide-marks afford the only good exposures on this coast. Approximately one-half of the Lower Bracklesham Series, from the base up to and including part of Fisher's Division IV, comes into this section of the bay; the beds following on in ascending order towards the south-east, and the outcrops of the firmer bands, which form the reefs, running obliquely across the foreshore in gentle curves convex to the north-west.

Near the entrance to Chichester Harbour, at a spot about three-quarters of a mile west-south-west of West Wittering Church, there are small exposures of dark-green loam with flint-pebbles, which probably marks the base of the formation. The loam contains much lignite in rolled pieces, often perforated by *Teredo*, and is succeeded eastward by laminated loams and clays comparable with those in Division I of the Whitecliff Bay section.

After an interval of about one-third of a mile, in which nothing is at present to be seen, grey and brown loam with seams of lignite and bands of nodular marcasite appear in a small reef opposite West Wittering Beacon, at the end of the lane running south from the village. Casts of small *Cardita planicosta* (Lam.) and of *Ostrea flabellula* Lam., occur freely in the nodules. Close to this spot, and apparently at a higher level on the shore, Mr. Clement Reid observed a sandy bed abounding in fruits of a *Nipa* palm. "These nuts," he writes, "are nearly as large as a cocoa-nut, and the species (*Nipa burtina*) corresponds with one found in beds of Bracklesham age in other districts. A closely allied species now living in tropical India and Malaya always flourishes in tidal estuaries, into which it sheds its nuts until they form a real hindrance to navigation. The fossil species must have occupied similar stations, for their nuts are invariably found in estuaries or marine strata, never in lacustrine deposits."[4]

For the next two miles the shore was destitute of exposures when the writer examined it, and to judge from earlier accounts the beds here usually are hidden by modern deposits. Mr. Reid, however, about 1885, noted indications of blue and green loams and clays at intervals over a space of about a quarter of a mile south-eastward from West Wittering Beacon; then blue clay with dwarf specimens of *Cardita planicosta* due south of Cakeham Manor Farm; followed by carbonaceous clays and sands with

[1] F. Dixon, 'Geology and Fossils, &c., of Sussex,' 1850, *London*; 2nd ed., 1878, *Brighton*.
[2] *Op. cit.*, pp. 73–76, 92, 93.
[3] C. Reid, 'Country around Bognor,' *Mem. Geol. Surv.*, 1897, pp. 5–8.
[4] *Op. cit.*, p. 7.

Teredo-bored lignite, beds of oysters, and a small, sharp-ribbed *Cardita*—the latter appearing at about 350 yards west of East Wittering Coastguard Station. At the same distance south-south-west of that station he found fine-grained, sandy, glauconitic rock full of bored lignite; but, beyond this, no other exposure short of Bracklesham Farm, where the more fossiliferous and better-known portion of the Bracklesham Bay section begins.

Green sandy clay with scattered flint-pebbles appears to the south of the Farm; then, south-eastward, greenish sands with *Cypraea tuberculosa* var. *coombi* J. de C. Sow.. capped by a mass of large *Cardita planicosta* in glauconitic marly sand. The reef that marks the oncoming of the famous Cardita Bed (= IV) has appreciably stronger relief than the ledges nearer Chichester Harbour, and though varying in width with the shifting of the shore-sand, it is seldom quite buried. Its western edge is gnawed by waves into miniature columns and arches whose sides are rough with myriads of projecting shells. Among the more abundantly represented forms associated with *Cardita planicosta* are *C. acuticosta*? (Lam.), *Arca planicosta* ? Desh., *Ostrea flabellula* Lam., *O. tenera* J. Sow., *Natica hantoniensis* (W. Pilk.), *Clavalithes longaevus* (Sol.), *Voluta selseiensis* Edw., *Turritella imbricataria* Lam., *T. sulcifera* Desh. Near the eastern limit of the reef (as at present exposed) the Cardita Bed is capped by a few inches of firm marly sand, forming the lower part of the "Turritella Bed," and crammed in places with *Turritellae* belonging to the *T. imbricataria* and *T. sulcifera* groups. Other notable fossils recorded from this horizon include, *Voluta cithara* Lam., *Conus lamarcki* Edw., and *C. diadema* Edw.

The outcrop of the Turritella Bed extends for a short distance south-eastward, into the area covered by Mr. Reid's memoir on the Bognor Sheet (332); and the remainder of the Bracklesham Bay section, described in that work, must here be dismissed in a few words.

Succeeding the Turritella Bed, after an interval of about half a mile, comes Dixon's "Palate Bed," with teeth and other remains of fish and serpents, correlated by Mr. Fisher with Division VI of Whitecliff Bay; then the "Little Park Bed," full of *Nummulites laevigatus* Brug. (= Division VII), followed by sands and clays with *Pectunculus pulvinatus* Lam. (*Axinaea*) and *Ostrea tenera* J. Sow., near the upper limit of the Lower Bracklesham Series.

The "Cerithium Bed" (IX) of the Upper Bracklesham appears about a quarter of a mile north-west of Thorney Farm, and the "Beloptera" and "Cypraea" Beds (= XIV) by the ruins of Medmerry Farm; then the "Hard Bed" with *Tellinae* (= XVI), and, lastly, the "Clibs" marl and limestone (= XVII), largely composed of foraminifera (*Nummulites variolarius* (Lam.), *Alveolina, Quinqueloculina, &c.*), of Selsey Bill and the Mixen Rocks.

2. *Hayling and Portsea Islands, and Spithead.*—Beds of Lower Bracklesham age occur in the southern part of Hayling Island. There seem to be no exposures. Some hard blue clays, appa-

rently at the base of the formation, were traversed in the upper part of a well-boring south of South Hayling Station.[1]

On Portsea Island the boundary of the Bracklesham Beds between Milton and Kingston is approximately determinable from the position of former openings in the Bagshot Sands, and some information concerning the beds in the lower part of the formation is afforded by records of well-borings at Portsmouth. These indicate the usual alternations of greyish or greenish clay and sand, and the presence of the basal pebble-bed.

In a sewer-trench opened on Southsea Common in 1866 Mr. C. Evans[2] observed (near the Royal Pier Hotel) a yellow sand containing, in great abundance, *Cardita planicosta* (Lam.) and *Turritella imbricataria* Lam., together with *Ostrea flabellula* Lam., *Cardium semi-granulatum* var. J. de C. Sow. (*Protocardia*), *Turritella sulcifera* Desh., *Fusus longaevus* Sol. (*Clavalithes*), and other fossils. He infers that this sand belongs to the lower part of the Bracklesham Beds. The predominance of the two species first named, and the seeming absence of *Nummulites* (on which Evans comments), strongly suggest a reference to Fisher's Division IV. In an adjacent boring (at Messrs. Long's Brewery) the base of the Bracklesham Beds seems to have been reached at a depth of 191½ feet.[3]

Under Spithead, Bracklesham Beds were found beneath marine deposits of post-Tertiary age in well-borings at the Horse Sand and Noman's (or Noman's Land) Forts, respectively two and three miles south of Southsea. In the Horse Sand well, 471¼ feet of Tertiary strata were traversed, consisting of partly-fossiliferous greyish and greenish sands and sandy clays. The whole thickness is referred to the Bracklesham Beds in the published records,[4] but there is reason to think that some of the strata belong to a newer formation. C. Evans[5] learned that "*Nummulina variolaria*" was found "in great numbers at a depth of about 300 feet below low-water mark" (*i.e.*, 200 feet below the top of the Tertiary strata), and that it had been met with also at "a considerably greater depth." Assuming, then, that the measurements of the Upper Bracklesham Beds at Whitecliff Bay hold good in this locality, about 80 feet of the Tertiary Beds bored through may be inferred to belong to the Barton Clay. It should be noted that the first mention of the occurrence of a characteristic Bracklesham fossil, *Cardita planicosta*, appears in the records at between 70 and 107 feet below the upper limit of the "solid" strata. The lower part of the well is clearly in the Lower Bracklesham.

As regards the boring at Noman's Fort, the details furnished appear to afford surer indications of the stratigraphical position of the 451½ feet of Tertiary beds (also classed as "Bracklesham") there traversed. The "brown-grey clay" with *Nummulites*

[1] 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, p. 97.
[2] 'Geology of the Neighbourhood of Portsmouth and Ryde,' *Proc. Geol. Assoc.*, vol. ii (1870–71), 1873, p. 158.
[3] 'Water Supply of Hampshire,' 1910, p. 120. Mr. W. Whitaker places the junction with the Bagshot Sands 55½ feet lower, but with a query.
[4] 'Geology of the Isle of Wight,' *Mem. Geol. Surv.*, 1889, pp. 310–312, and 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, pp. 169, 170.
[5] *Op. cit.*, p. 158.

variolarius, Corbula, Pinna margaritacea, Pecten corneus, &c., encountered between 374 and 385 feet from the top of these beds may, with much probability, be correlated with the "Brook Bed" Division XIV; while the "green-grey" bed with *Cerithium giganteum* and *Turritella imbricataria*, in which the boring ended, between 58½ and 67 feet farther down, may similarly be referred to Division IX. The interval between these two beds is about the same as at Whitecliff Bay, 4½ miles distant. Unless, therefore, the higher members of the Upper Bracklesham have greatly expanded, the Noman's Fort section should include over 200 feet of Barton Beds.

3. *Gosport and Lee-on-Solent.*—About Gosport the strike is approximately parallel with the coast at Stokes Bay, and the ground being nearly level, the dip of 2° to 3° south-westward brings in higher beds in fairly quick succession in that direction, so that the upper limit of the Bracklesham Beds probably lies not far from the shore south and west of Alverstoke.

A pit a quarter of a mile south of Hardway exposed a few feet of interbedded sand and loam near the junction with the Bagshot Sands, which crop out close by. Records of wells in Gosport, farther south, show the increasing thickness of the Bracklesham clays and sands towards the coast, *e.g.*, Royal Clarence Victualling Yard (south of Priddy's Hard), 35¾ feet; New Barracks (Forton), 91½ feet; Gosport Water Works, at Bury Cross, 291 to 294 feet. The presence of lignite and shell-beds is noted, and in most cases the pebbly sand at the junction with the Bagshot Sands can be distinguished with some degree of confidence.[1] An examination of specimens from the earliest of the Bury Cross borings enabled Mr. O. Fisher to identify parts of the Lower Bracklesham groups C and D, the fossiliferous divisions numbered VII, VI and IV occurring at depths between 39¼ and 104 feet from the top of the bore-hole. Mr. Fisher points out[2] that these divisions are thinner than at Whitecliff Bay. He seems to be mistaken, however, in thinking that the unfossiliferous laminated beds beneath them "continue of nearly the same thickness," for, as Mr. W. Whitaker[3] has lately shown, the base of the Bracklesham Beds in the Bury Cross section is almost certainly 102 feet below the horizon to which it is assigned by Mr. Fisher. With this additional thickness, the interval between Division IV and the junction with the Bagshot Sands would be about 200 feet, as at Southsea (p. 25), compared with 123 feet in the Whitecliff section.

By Haslar Hospital *Nummulites variolarius* has been observed in clay occasionally exposed on the shore,[4] and the same species, associated with *Pseud-amusium corneus* in a blue clay which Mr. Fisher refers to Division XVII, was noted in a temporary excavation at Fort Gomer, south-west of Privett.

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[1] *See* 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, pp. 85–93.
[2] 'On the Bracklesham Beds of the Isle of Wight Basin,' *Quart. Journ. Geol. Soc.*, vol. xviii, 1862, p. 77.
[3] 'Water Supply of Hampshire,' 1910, p. 91.
[4] C. Evans, *op. cit.*, p. 157.

The best exposures of Bracklesham Beds in the area covered by this memoir occur in the cliffs and on the shore at and north-west of Lee-on-Solent. As in Bracklesham Bay, one traverses an ascending sequence when following the coast in a south-eastward direction, but the general section near Lee-on-Solent begins higher in the Series, namely near the top of the Lower Bracklesham, and ends at a horizon closer to the base of the Barton Beds.

Between Brownwich Farm (in the north-eastern corner of Sheet 330) and Titchfield Haven grey-green loamy sand, weathering yellow, appears in several places from beneath the Plateau Gravel which forms the greater part of the cliff. Casts of *Turritella*, mentioned by Mr. Fisher, seem to be the only fossils known from this locality.

At Hill Head, east of the Haven, sands of a lighter tint rise well above the beach, but as the sea has there ceased to encroach upon the land the face of the cliff has become much obscured by bush-grown talus, and the fossil-beds formerly visible are no longer to be seen. In 1856 Mr. Fisher observed, at the base of the sands, and resting on laminated clay, "a lenticular mass of fossil shells with *Cerithium giganteum*, washed together, partly encrusted with septaria, partly free."[1] He remarks that the position of this fossil-bed in the general section, as well as the assemblage of shells, prove it to be on the horizon of Division IX, that is to say, at the base of the Upper Bracklesham Series.

On the shore south-west of the gap at Lane End (south of Stubbington) there is a small spit of subangular shingle which is remarkable for the abundance of drifted Bracklesham fossils, mingled with modern shells, that are strewn over it; *Cardita planicosta* (Lam.), *Axinaea pulvinatus* (Lam.), *Turritella imbricataria* Lam., and *T. sulcifera* Desh. being especially noticeable. The fossil shells are bleached and often water-worn, but many retain their ornamentation, and all have acquired a degree of induration such is seldom possessed by Bracklesham fossils *in situ*. Mr. Fisher thinks that they are derived from a submerged part of the outcrop of the Cerithium Bed, noticed at Hill Head.

The interrupted section shown in the mile-and-a-quarter of coast-line between Lane End and Elmore Halt[2] has been described in some detail both by Mr. Fisher[3] and by the late Caleb Evans.[4] The former writer calculates the total thickness of strata outcropping there to be $106\frac{3}{4}$ feet. The thicknesses assigned to the several beds or groups of beds in the later and fuller account by Evans agree substantially with those given by Fisher, and are adopted below.

The first and lowest bed seen to the east of the gap is a dark-green loamy sand with *Pseud-amusium corneus* (J. Sow.), and a band ($1\frac{1}{2}$ feet) rich in *Protocardia semigranulata* var. (J. de C. Sow.) at the top. Fisher, who divides this sand into three beds, gives the total thickness as 6 feet 3 inches.

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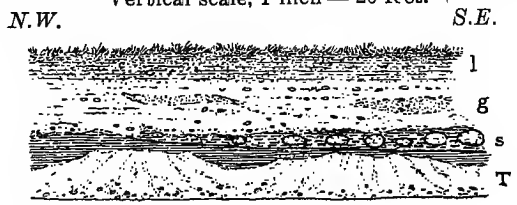
[1] *Op. cit.*, p. 78.
[2] Half a mile south-by-east of *Lee* on the map.
[3] *Op. cit.*, pp. 77, 78.
[4] *Op. cit.*, pp. 154–157.

Next comes dark greyish and brown sandy clay with *Dentalium sp.*, and *Cytherea lucida* J. de C. Sow. (*Meretrix nitidula* (Lam.)) in the lower part, 6 ft. 9 in.

The dark-green loamy sand (3 ft. 8 in.) which follows is the most conspicuous bed in the section, as it contains many spheroidal and bun-shaped septarian concretions (often over a yard in diameter) which project from the face of the cliff, and form a reef of boulders along the outcrop of the bed on the shore (Fig. 6). Where unweathered the sand abounds in small fossils, notably *Nummulites variolarius* (Lam.), *Corbula pisum* J. Sow., and minute gasteropods (*Turritellae, &c.*)—the *Nummulites*, hitherto unrecorded from this bed, being exceedingly common. The speckled calcareous sandstone composing the septarian "doggers" has the greyish-green tint and confused burrow-markings often seen in the calcareous beds of the Upper Greensand formation. In it are preserved many fossils which are less noticeable in the surrounding sand, such as *Fustiaria striata* (J. Sow.), *Carditae*, full-sized common *Turritellae*, *Fusus sp.*, and *Conus velatus*

FIG. 6.—*Septaria-bed in the Upper Bracklesham Series, Lee-on-Solent.*

Vertical scale, 1 inch = 20 feet.



l. Stony loam.
g. Plateau Gravel, with inclusions of loam.
s. Septaria-bed, overstepped by Plateau Gravel north-westward.
T. Talus.

J. de C. Sow. Calcified wood with groups of *Teredo*-borings is not uncommon.

The septaria-bed is overlain by about 17 feet of dark loamy sands with yellow streaks and apparently unfossiliferous, succeeded by laminated sandy clay with *Pinna margaritacea* Lam., and tabular septaria containing bored wood and clusters of small shells—mainly *Corbula pisum* J. Sow. Mr. Fisher notes that "there is sometimes coarse drift-sand on the eastern side of the logs" of wood. This bed (6 feet 7 inches thick) is not now exposed, but detached septaria from it can be seen on the shore.

The next bed, at present exposed in a low ledge at the foot of the cliff by the western stairway to the beach, is a dark-grey fossiliferous loam, between 6 and 7 feet thick, and having a band of *Cardita planicosta* (Lam.) at the base. It is richer in molluscan species than any other bed in the section, and is correlated by Fisher with his Division XIV or "Brook Bed." A few small flint-pebbles are scattered through the loam. Among the commoner fossils are *Nummulites variolarius* (Lam.), *Pseudamusium corneus* J. Sow., *Pecten triginta-radiatus* J. de C. Sow., *Ostrea flabellula* Lam., *Sanguinolaria hollowaysi* J. Sow. (*Garti*?),

Cytherea obliqua Desh. (*Meretrix*), *Crassatella plicata* J. Sow., *Natica*, several spp., *Turritellae*, *Xenophora agglutinans* (Lam.), *Rostellaria lucida* J. Sow., *Pleurotoma denticulata* Bast., *Conus lamarcki* Edw., *Cassidaria coronata* Desh., *Voluta selseiensis* Edw., *V. luctatrix* (Sol.), *Strepsidura turgida* (Sol.), *Clavalithes longaevus* (Sol.).

The overlying "Corbula Bed," comparable with the upper part of Division XIV at Whitecliff Bay, is a dark greenish-blue clay, 4½ feet thick, crowded with *Corbula pisum* J. Sow., and containing also many minute gasteropods. It appears in a ledge, close to the cliff, between 300 and 330 yards north-west of the pier.

Between the exposure of the Corbula Bed and the pier the solid strata are at present hidden by talus and shingle. To judge from the published descriptions of the section, and from the character of the material thrown out of a temporary excavation by the railway station, this interval is occupied by the outcrop of an unfossiliferous liver-coloured clay (3 feet 14 inches), and an overlying greenish sandy marl (4½ feet) with a layer of big *Cardita planicosta* at the base, a profusion of *Nummulites variolarius* in the middle, and a band of *Pseud-amusium corneus* at the top. This greenish marl is doubtless the equivalent of the "*Nummulites variolarius* Zone," (XVII) of Whitecliff. In a sample of calcareous sandy clay obtained, probably, from the lower part of this bed, Mr. F. Chapman[1] identified 22 species, including the characteristic *Nummulites* (stated to be "excessively common"). *Turbinolia humilis* Edw. and Haime, *Orbitulifera petiolus* J. de C. Sow., *Pleurotoma callifera* Edw., *Solarium canaliculatum* Lam., and several ostracods. A similar marly clay was lately proved, near the level of the upper limit of the beach, to the east of the pier, in an excavation for a tank on the south side of the yard at Lee Station; the first three of the species named in the above list being abundantly represented on the spoil-heaps, together with *Fustiaria nitens* (J. Sow.) (*Dentalium*), *Turritella sulcifera* Desh., and fragments of *Voluta* and *Clavalithes*.

The *Nummulites variolarius* Bed is succeeded by about 33 feet of greenish-blue sandy clay (now hidden), the highest 6 inches of which contains "rather abundantly a coral like *Paracyathus caryophyllus* [Dunc.] . . . and crushed *Dentalia*, with a few Bivalves, species indistinguishable."[2] The thin band yielding these fossils is correlated by Mr. Fisher with the "Huntingbridge Beds" of the New Forest (= XIX).

The highest member of the Bracklesham Beds observed on the coast near Lee-on-Solent is a light-green to greenish-blue silty clay (14½ feet), apparently devoid of fossils. It is now to be seen only in a strip of foreshore near low-water mark of spring tides, about midway between Lee Station and the groyne by Elmore Halt. Fisher excludes it from the Bracklesham Beds, but there is no reason to doubt that it belongs to that lithologically similar part of his Whitecliff Division XIX which has since been proved to lie below the junction with the Barton Clay.

[1] 'On the Microscopic Contents of a Sample of Bracklesham Clay from Lee-on-Solent, Hampshire,' *Geol. Mag.*, 1897, pp. 226, 227.
[2] O. Fisher, *op. cit.*, pp. 77, 78.

CHAPTER VII.

BARTON BEDS.

While the broad lithological difference between the Barton Clay and the Barton Sands is too pronounced to be ignored in "formation" maps such as those of the Geological Survey, the richly fossiliferous beds which they jointly comprise so clearly form parts of a single series in the type-section near Barton that it will be more convenient here to consider these two divisions together, under the above heading.

The Barton Beds are not known to occur on the mainland in the area of the Portsmouth map-sheet (331), though, as already remarked, their outcrop beneath the waters of Spithead and the eastern Solent must closely approach the coast in the vicinity of Lee-on-Solent and Alverstoke. They emerge on the western shore of Southampton Water, and extend throughout the mainland area of the Lymington Sheet, where, however, they are so much overspread by the Headon Beds and Plateau Gravel that they can be seen only here and there, on the sides of some of the river-valleys, until one reaches the neighbourhood of their western limit, in the country lying between the coast at Barton and Rhinefield Walk.

In their exhaustive paper on "The Upper Eocene, &c." Messrs. J. S. Gardner, H. Keeping, and H. W. Monckton[1] divide the Barton Beds into three stages, namely, (1) Lower Barton or Highcliff Beds, consisting mainly of sandy clays; (2) Middle Barton or Barton Clay proper, more decidedly argillaceous, and (3) Upper Barton, mostly sandy. Of these, the first and second nearly correspond to the Barton Clay, and the third to the Barton Sands, of the Geological Survey map.[2] Numerous subdivisions are recognised which will be noticed in the sequel.

The base-line of the Barton Beds is drawn at the lower limit of the occurrence of *Nummulites elegans* Rup. Jones. No evidence of a break in the stratigraphical succession has been observed at this horizon in the few clear exposures that are known. At Whitecliff and Alum Bays, in the Isle of Wight, the thin bed containing *Nummulites elegans* lies well within the limits of a group of dark sandy clays in which an Upper Bracklesham fauna is gradually augmented rather than replaced by incoming Upper Eocene (Barton) species; and even in the Highcliff section on the main-

[1] *Quart. Journ. Geol. Soc.*, vol. xliv, 1888, pp. 578–633. The paper gives references to the literature of the Barton Beds, and tabular lists of fossils. *See also* R. B. Newton, 'Systematic List of the F. E. Edwards Collection of British Oligocene and Eocene Mollusca,' *Brit. Museum* (*Nat. Hist.*), 1891.

[2] *I.e.*, the New-Series map, 1-inch scale. In the Special Isle of Wight Sheet, and in the memoir on that Island, 2nd ed., 1889, the Barton Sands are termed "Headon Hill Sands." The name Upper Bagshot Sands or Beds, also formerly applied to the Barton Sands, has been abandoned as misleading, the Upper Bagshot Beds of the London Basin apparently belonging to some part of the Upper Bracklesham-Lower Barton stage.

land, where a change occurs in the character of the sediment a little below this horizon, the mollusca in the beds for 20-feet above the *N. elegans* Zone "generally seem . . . to be of species common to both the Barton and Bracklesham Series."[1] Messrs. Gardner, Keeping, and Monckton, indeed, point out that the fauna of the Lower Bracklesham "differs far more from that of the Upper Bracklesham, than the latter does from that of the Bartons," but admit that no better base for the Barton Beds can be found "without trenching very considerably on the Bracklesham,"[2] as defined by Mr. Fisher.

The Lower and Middle Bartons are marine deposits but appear to have formed not far from the mouth of a large river, for the spoils of land vegetation are common in them, and drifted fresh-water shells also are frequently encountered. The more peculiarly Bartonian elements of the marine mollusca indicate water of lower temperature than that in which the Bracklesham Beds were laid down: many species which give a tropical aspect to the fauna of the beds below disappear, and some temperate London Clay forms return. This change is usually ascribed to an alteration in the geographical conditions, such as an opening of a strait to the north, or the shutting out of warm currents by an uplift of land on the south-west. The Middle Barton closes with a widespread drift of broken shells, and the Upper Barton, in which a marine fauna gives place to a brackish one, records the progressive shoaling of the water that eventually introduced the lacustrine regime of the Lower Headon.

As far as can be seen, the Barton Beds vary little in thickness and other respects in the New Forest area. When, however, their development at Highcliff and Barton is compared with that in the sections at either end of the Isle of Wight, they are found to undergo a thickening, east and south-eastward, which affects all three divisions and is most marked in the Upper Barton, as appears from the subjoined table, wherein the measurements are given in feet.[3]

		Barton.	Alum Bay.	Whitecliff Bay.
Barton Beds	Upper	90	114	221
	Middle	53	167	92
	Lower	49	57	55
		192	338	368

The Barton Section.

Of the typical section presented on the coast of Christchurch Bay between Highcliff (or Highcliffe) and Long Mead End, no more than the eastern or upper stratigraphical half lies within the area of the Lymington Sheet, and in order to review the ascending sequence of strata between the Bracklesham and the Headon Beds it is necessary to traverse some of the ground covered

[1] Gardner, Keeping, and Monckton, *op. cit.*, p. 587.
[2] *Op. cit.*, pp. 601, 602.
[3] Gardner, Keeping, and Monckton, *op. cit.*, pp. 594, 600, 604.

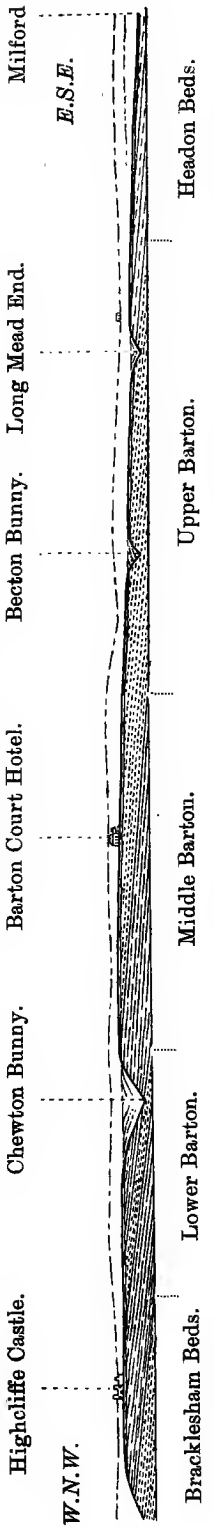


FIG. 7.—*Coast-section, Highcliff to Milford.*
Distance, about 6 miles.

by the memoir on the Bournemouth Sheet[1] (329), beginning at a point $2\frac{1}{4}$ miles west of Barton Court Hotel (fig. 7).

Near the middle of the bay, where the Barton Beds are developed, the cliffs are from 100 to 115 feet high, and almost level at the top, except in the neighbourhood of the gaps at Chewton Bunny and Becton Bunny. A gentle dip rather south of east brings each bed down to the level of the beach at a distance of from one to two miles from the spot where it comes in beneath the thick spread of Plateau Gravel forming the upper part of the cliff, but the section is a good deal obscured by the landslips noticed on an earlier page (2); and protective works carried out at Highcliff in recent years have destroyed the greater part of the Lower Barton exposure.

Lower Barton.—The junction with the Bracklesham Beds comes down to the shore half a mile west of Chewton Bunny, but is most clearly seen above the talus under Highcliffe Castle, farther west. The white or yellowish sands which there occupy most of the Bracklesham part of the section are overlain by an irregular band of flint-pebbles[2] in a ground-mass of dark loam, which passes up into glauconitic sandy clay exhibiting a curiously bright green streak. Ten feet above the pebble-bed, the green clay—which yields casts of shells, *Teredo*-bored wood, and fir-cones—is capped by a band of coarse, ferruginous clayey sand ("ironstone"), about 9 inches thick, which forms the highest number of the Bracklesham Beds (fig. 8).

In the *Nummulites elegans* Zone (8 to 10 inches), which immediately succeeds, the name-fossil is less abundant than in the Isle of Wight sections, and on weathered surfaces is difficult to discern. The dark green sandy clay in which the nummulites are embedded, along with casts of shells, continues

[1] By C. Reid, 1898, p. 8.

[2] For purposes of mapping, the base of the Barton Beds is drawn at or about the horizon of this pebble-bed, where a marked lithological change occurs.

upward for about 10 feet, when it merges into stiff drab clay (10 feet) containing a pink band about 4 feet from the top. Among the fossils plentiful at this horizon are casts of an echinoderm, *Voluta athleta* (Sol.), *Cassis ambigua* (Sol.), *Hippochrenes amplus* (Sol.), and the characteristic Barton form *Pleurotoma rostrata* (Sol.). Teeth and bones of fish also are noticeable. The next 13 feet is occupied by paler drab clay with lenticles of sand.

The Lower Barton terminates in the Highcliff Sands—a division 16 feet thick, consisting of glauconitic clayey sand with impersistent intercalations of fine angular quartz-sand, crowded with small and well-preserved shells referable to a large number of species. Among the genera represented are *Bulla*, *Odostomia*, *Rissoa*, *Turbonilla*, and *Pyramidella*. Specimens of *Ophiura wetherelli* Forbes are occasionally met with in the upper part of the Sands, and *Pholadomya margaritacea* J. Sow., in the living position, occurs abundantly in a rusty-weathering glauconitic band at the top.

According to Messrs. Gardner, Keeping, and Monckton the Lower Barton fauna numbers between 300 and 400 species, the most characteristic forms being among the minute gasteropods, such as *Canarium bartonense* (J. Sow.), *Cominella canaliculata* J. de C. Sow., *Acera striatella* (Lam.), and *Volvaria acutiuscula* J. and G. B. Sow.

Middle Barton.—This stage may be readily distinguished from the stages above and below owing to the circumstance that it includes all the conspicuous bands of septarian concretions occurring in the Barton section. The lower of two such bands, 5 feet apart, marks the base of the Middle Barton. The clay between them yields *Voluta suspensa* (Sol.) and a *Fusus*, both confined to this horizon; and drifted plant-remains.

For about 30 feet above these septaria bands, the clay—here more sandy than below—contains little of interest; then, just above another course of tabular septaria, there follow two thin bands, 1½ feet apart, exceedingly rich in fossils, the most noteworthy of which are *Ostrea gigantea* Sol., *Voluta luctatrix* (Sol.), *V. ambigua* (Sol.), *Sycum pyrus* (Sol.), *Clavalithes longaevus* (Sol.), *Murex minax* Sol., *Cassis nodosa* (Sol.). These fossil-bands come down to the shore under the old Coastguard Station, west of Barton Court Hotel. They are succeeded by 12 feet of dark and light slate-coloured clays with pockets of delicate shells (*Turritella granulosa* Desh., *Corbula pisum* J. Sow., *&c.*), and with a well-marked layer of flat septaria 4 feet from the top.

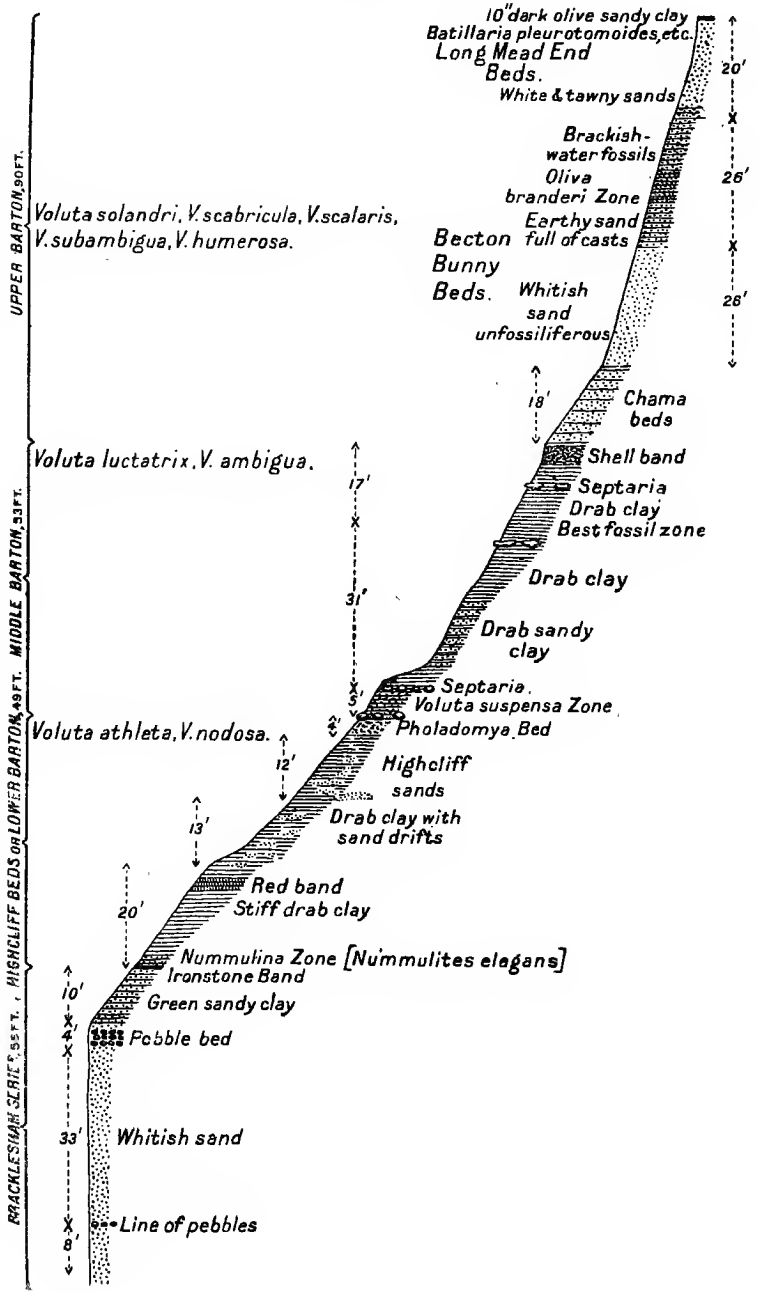
The highest member of the Middle Barton is a bed of comminuted shells, mostly *Turritellae*, in a dark-yellow and red ferruginous matrix. This bed thickens eastward, from about 2 feet at Highcliff to 15 feet at Barton. It hardens sufficiently on exposure to be used for building. Indurated slabs lie on the beach, and those which retain portions of the upper surface of the bed often exhibit unbroken specimens of *Tellina ambigua* J. de C. Sow. and *T. branderi* J. de C. Sow.

"The fauna of the Middle Division of the Bartons," write Messrs. Gardner, Keeping, and Monckton,[1] "is nearly as rich as

[1] *Op. cit.*, pp. 589, 590.

FIG. 8.—*Profile-section of the Barton Beds, Barton Cliff.*

(Adapted from Gardner, Keeping, and Monckton, *Quart. Journ. Geol. Soc.*, vol. xliv., 1888, opp. p. 594).



that of the lower, and far more characteristic, consisting of upwards of 250 species. Very few of those peculiar to this stage are, however, either common or conspicuous, and perhaps the only one worth citing is *Fusus lima* [*Chrysodomus*]. . . Several small but well-known species, such as *Conus dormitor* [*Conorbis*] and *Buccinum desertum* [*Cominella*], make their first appearance here." The only mammal recorded from the type section of the Barton Beds, the cetacean *Zeuglodon wanklyni* Seeley,[1] was found in one of the clay beds of this stage.

Upper Barton, or Barton Sands.—At the base of this division a few feet of buff sandy clay, with *Voluta subambigua* (Sol.) and an abundantly represented species of *Turritella*, is succeeded by a bluish-grey loamy sand (18 feet), known as the Chama Bed, which dips to the level of the beach about one-third of a mile east of Barton Court Hotel.

Where the Chama Bed is covered by sand and gravel only, that is to say, throughout the greater part of its exposure, it seldom yields any organic remains; but as soon as the protective clays at a higher horizon appear above it in the cliff it becomes extremely fossiliferous; *Chama squamosa* Sol., with valves usually united, occurring in profusion, especially towards the top of the bed; while *Turritellae* abound near the base. Among other species common in the lower half of this bed are *Voluta costata* Sol., *V. humerosa* Edw., *Typhis fistulosus* Broc., *Cypraea bartonensis* Edw. Above come *Seraphs sopitum* (Sol.) and *Vulsella sp.;* and still higher, in the thick of the Chamas, a group of lamellibranchs comprising many species of *Tellina, Lucina, Panopaea, Solen* and other genera, a large proportion of the individuals having apparently died on the spot. Here, too, occur the echinoid spines referred to *Cidaris websteriana* Forbes. "The fauna contains altogether 170 known species, and differs, as a whole, more from that of the Lower and even Middle Barton than does that of the Lower Barton from the Upper Bracklesham."[2] Many species present in the clayey beds below are wanting here, and others are scarce, stunted, water-worn, or represented by modified forms. This marked change in the fauna is to be ascribed to an immigration of species consequent upon the substitution of clear water and a sandy sea-bed for the turbid water and oozy bottom of Middle Barton times, rather than to evolutionary progress on the spot.

The overlying Becton Bunny Beds are divisible into an upper and a lower part, each about 20 to 26 feet thick. The lower division consists of greyish micaceous sands in which the grains are bound together by fine argillaceous matter. It is unfossiliferous but has a piped structure indicative of the former presence of annelids and other burrowing animals. The upper division is composed partly of brown earthy sands with casts of marine

[1] Some bones of this animal are preserved in the Dent Collection of Barton Fossils, lately acquired by the Bournemouth Natural Science Society. *See* Sir Daniel Morris in 'A Natural History of Bournemouth and District,' *Bournemouth*, 1914.

[2] Gardner, Keeping, and Monckton, *op. cit.*, p. 591.

shells, followed by dark grey and green clays and sandy clays, with a mixture of marine and freshwater molluscs, which increase in number towards the top. In the lower beds of this division, *Oliva branderi* J. Sow. and *Potamides funatus* (J. Sow.) var. (=*Cerithium variabile* Desh.) are among the most notable forms; while the brackish-water beds above yield *Potamomya plana* J. Sow. (*Erodona*), *Cyrena*, *Dreissensia*, *Neritina concava* J. de C. Sow., *Marginella simplex* Edw., *&c.*

The Long Mead End Beds—fine, white and yellow, slightly loamy sands, about 20 feet thick—are unfossiliferous for about 15 feet above their base, but farther up contain seams and pockets of shells including *Psammobia ? rudis* (Lam.), *Lucina gibbosula* Lam., *Cyrena deperdita* (Lam.), *Bayania hordeacea* (Lam.), *Batillaria pleurotamoides* Lam (*Cerithium*), *Oliva branderi* J. Sow., *&c.* Remains of turtles are met with at this horizon.

A thin band of green sandy clay with *Batillaria pleurotomoides* and *Cyrena deperdita* marks the top of the Long Mead End Beds, and of the Barton Series.

Inland Exposures.

Clayey beds, belonging presumably to the Middle Barton, crop out in the valley of the Ober Water west of Brockenhurst, and in the lower part of the bluff overlooking Southampton Water at Fawley, but in neither locality are there any clear sections.

The sands of the Upper Barton occupy a larger area at the surface; underlying most of the heath-land in Rhinefield Walk, and appearing also in several valleys in other parts of the Lymington district. The sections presented in sand-pits and cuttings are of little interest, for near the surface the fossils have almost always been dissolved away by percolating rain-water, leaving at best only indistinct casts in iron oxide.

There are road-side excavations in white and yellow sands at Clay Hill; on the slope north-west of Kettlethorns near Sway; on Five Thorns Hill and north-east of Ober Farm, west of Brockenhurst. Pieces of ironstone are common in the sandy soil on Hincheslea Moor.

The junction with the Headon Beds was formerly well shown in the railway cuttings at and east of Long Slade Bottom; also in pits by the Gas Works at Lymington, and to the south-west of Walhampton House on the opposite side of the valley.

Farther east, fine sands are exposed in pits east of Hughs Common and south of Mopley Pond,[1] near Langley; and in the low cliff on the coast by Eaglehurst.

[1] The ground here is coloured as Headon Beds on the 1-inch map, though not on the 6-inch field-map (Sheet 81, Hants) at the Geological Survey Office.

CHAPTER VIII.

HEADON BEDS.

The thinly-bedded marls, clays, sands, and lignites which make up this formation immediately underlie the superficial deposits throughout the greater part of the Lymington District.

Here, as in the Isle of Wight, three divisions are recognisable: a Lower, fresh and brackish-water, group; a Middle, marine group—more purely marine than in the Isle of Wight; and an Upper group, mainly of fresh-water facies, as far as can be seen. Their maximum aggregate thickness may amount to about 150 feet, but a satisfactory estimate is hard to arrive at, for the Lower Headon varies much in its development, and it is doubtful, too, whether all the Tertiary strata locally overlying that division are of Headon age. The greatest thickness of solid beds so far proved above the Barton Sands is 168 feet, in a well-boring at Lady Cross Lodge, on the north-western edge of the Beaulieu Heath plateau; and, having regard to the tectonics of the district, it appears probable that this measurement falls short of the actual maximum. Of the 168 feet of post-Barton beds traversed in that boring, not more than 15 feet can be assigned to the Lower Headon, on the evidence of the fossils identified by Mr. Clement Reid.[1] Deducting this figure, there remains a balance of 153 feet, to be apportioned between the Middle Headon and newer beds. But at Cutwalk Hill, near Lyndhurst, a few miles north of this district, Mr. E. B. Tawney[2] observed a small outlier of Osborne Beds at a level about 100 feet above that of the base of the Middle Headon; hence it is not improbable that some of the lower beds of the Osborne Series occur within the area of the Lymington map, beneath the Plateau Gravel on Beaulieu Heath. The thickness of the Lower Headon near Lymington ranges from about 15 to 80 or 90 feet; that of the Middle Headon is about 25 to 30 feet, while the thickness attained by the Upper Headon remains uncertain, unless the Osborne Beds are assumed to be absent, in which case it may be set down as rather more than 120 feet.

Lower Headon.

This stage is well shown in Hordle (or Hordwell) Cliff, between Becton Bunny and Milford. The bedding-planes there have a gentle south-eastward dip, decreasing towards Milford, where they are nearly horizontal. Comprising many thin and often

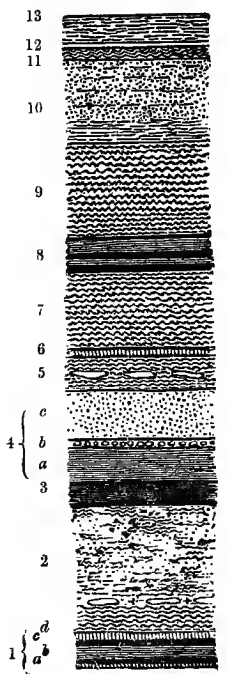
[1] In the 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, p. 64.
[2] 'On the Outcrop of the Brockenhurst Bed near Lyndhurst,' *Geol. Mag.*, 1883, p. 159.

inconstant stratulae more or less rich in organic remains, the Lower Headon gives scope for varied schemes of subdivision and classification, and in these respects, as well as in the thicknesses assigned to particular beds, the accounts given of the Hordle sec-

FIG. 9.—*Section of the Lower Headon Beds, Hordle Cliff* (Gardner, Keeping, and Monckton).

Scale, about 1 inch = 24 feet.

(From *Quart. Journ. Geol. Soc.*, vol. xliv, 1888, p. 596, with alterations in letterpress.)



tion by different observers actually exhibit a considerable amount of diversity.[1]

The tabular summary of the succession given below is a

[1] The following are among the numerous works dealing with the Hordle Cliff section :—

S. V. Wood,' On the discovery of an Alligator, &c.,' *Geol. Journ.*, i, 1846, p. 1.

Marchioness of Hastings, ' Description géologique des falaises d'Hordle, &c.,' *Bull. Soc. Géol. France*, ser. 2, t. ix, 1852, p. 191.

T. Wright, ' A Stratigraphical Account of the Section of Hordwell, &c.,' *Proc. Cotteswold Club*, i, 1852, p. 120.

E. B. Tawney and H. Keeping, ' Section at Hordwell Cliffs, &c.,' *Quart. Journ. Geol. Soc.*, vol. xxxix, 1883, p. 566.

J. S. Gardner, H. Keeping, and H. W. Monckton, ' The Upper Eocene, &c.,' *ibid.*, vol. xliv, 1888, p. 578.

modification of that published by Messrs. Gardner, Keeping, and Monckton in 1888,[1] and by the last-named author in 1910.[2]

SECTION OF THE LOWER HEADON BEDS AT HORDLE CLIFF.—(FIG. 9).

		ft.	in.
Plateau gravel		—	—
Lower Headon Beds	13. Marl, iron-stained	3	0
	12. Limnaean marl (dark layer with serpents' vertebrae, rodents' teeth, etc., 1 in. thick)	0	9
	11. Greenish rusty marl, with broken turtle and mammal bones	1	8
	10. Laminated sand, with grey partings of clay, darker towards the base, passing down into the Unio Beds, with *Unio*, *Viviparus*, *Potamaclis*, in nearly slate-coloured clay. At the bottom there is a layer of seeds	11	0
	9. Bright, green marly clay, with crushed *Limnaea* ...	12	0
	8. Chara Bed. Lignite and drab clays, with roots, rushes, &c., then lignite, with roots, rushes, and seeds at base	3	9
	7. Greenish mottled clay and marl, various kinds, with a black band 4 in. thick near base; *Dreissensia*, *Limnaea*, &c.	10	4
	6. Limnaean limestone	0	7
	Black band	0	1
	5. Ironstone Bed. Mottled green marly clay, with masses of clay and ironstone up to several tons in weight	4	0
	4. Crocodile Beds: (*c*) Very fine pale grey sand, becoming darker at base and more clayey. Layers of *Erodona plana* at top and bottom. Crocodile-bones with *Cancellaria pyrgata* one-third down...	6	4
	(*b*) Coprolite bed, with rolled bones and comminuted shells: a thin black layer at bottom	1	0
	(*a*) Stiff marly clay, becoming clunchy	4	0
	3. Leaf Bed. Dark, sandy clay, slightly mottled with yellow, and with roots passing down into drab pipe-clay, with black roots and partings ...	3	2
	2. Mammalia Bed. Bright green marl, with roots. *Viviparus* drifted in pockets. An iron band 8 in. thick, below which there is mottled green marly clay	17	0
	1. Basal Lignite Beds. (*d*) Impure friable lignite and clay	2	2
	(*c*) Black clay with *Erodona Dreissensia*, *Mytilus* and *Cancellaria pyrgata* ...	0	7
	(*b*) Black clay with roots and occasional broken *Erodonae* ...	0	10
	(*a*) Lignite, with fish scales; sand at base, ½ in. thick, with *Cyrena*	0	3
Barton Beds		—	—
		82	6

[1] *Quart. Journ. Geol. Soc.*, xliv, p. 596.
[2] 'Geology in the Field' (*Geol. Assoc.*), p. 283.

The lignitic group (1) at the base, while varying much in thickness, forms probably the most persistent part of the Lower Headon, and its presence facilitates the recognition of the inferior limit of the Headon Beds in poor exposures inland. The principal molluscan species represented are *Dreissensia brardi* Faujas, *Erodona plana* (J. Sow.) (*Potamomya*), *Cyrena cycladiformis* Desh., *Cancellaria pyrgata* Edw. MS., and *Melanopsis fusiformis* J. Sow.

The famous Mammalia Bed (2), so successfully worked by Barbara Marchioness of Hastings about the middle of the last century, has yielded little of interest in recent years. Most of the vertebrates recorded from this bed (or group of beds) were found above the 8-inch layer of ironstone, and include the reptiles *Diplocynodon hantoniensis* (S. Wood), *Trionyx incrassatus* Owen, *Ocadia hordwellensis* (Seeley) (*Emys* Auct.); several genera of birds, *Grus*, *Idiopsis*, *Actiornis*, *&c.*; and the mammals *Anoplotherium commune* Cuv., *Paloplotherium*, *Anthracotherium minus*? Cuv., *&c.*

The Leaf Bed (3) expands westward of Long Mead End and in one place is about 10 feet thick. Impressions of leaves are best preserved where the bed is thin. The flora includes *Equisetum*, *Salvinia*, *Chrysodeum*, *Arthrotaxis*, large feather-palms, rushes, &c.

In the Crocodile Beds (4), which come into the section at Long Mead End, a sandy band (*b*), known as the "Coprolite" or Rolled-bone Bed, contains water-worn teeth, bones, and plates of *Ocadia*, *Trionyx*, and *Diplocynodon* (the so-called crocodile); while in the thicker bed (*c*), above, *Diplocynodon hantoniensis* (S. Wood) is associated with remains of *Lepidosteus*, *Ocadia crassa* Owen (*Emys*), several species of *Trionyx* (*T. henrici* Owen, *T. marginatus* Owen, *&c.*), and numerous mammals, *e.g. Paloplotherium annectans* Owen, *Dichodon cuspidatus* Owen, *Viverra hastingsiae* Davies, *Hyaenodon minor* Gervais, *Microchoerus*, *Adapis*, *&c.* West of Long Mead End the Crocodile and Leaf Beds are interrupted for a distance of about 200 yards by a contemporary river-channel, filled with confusedly-stratified clays and sands containing much drift-wood.

Bed (5), with its tabular masses of ironstone, and the overlying band of cream-coloured limestone (6), largely composed of *Limnaeae* (several species) together with *Planorbis goniobasis* (Sandb.) and seed-vessels of *Chara*, make conspicuous features in the cliff-section south-west of Hordle House; while the less persistent sandy and lignitic Chara Bed (8), in which seeds of *Chara*, *Typha*, and other plants occur in profusion, is best exposed by Paddy's Gap, half a mile south-east of that House.

The succeeding green and grey marls, and laminated sands (9, 10) contain shelly layers which are most marked in the Unio Beds, near the middle of this group. The shells include *Unio solandri* (J. de C. Sow.), *Potamaclis turritissima* (Forbes), *Limnaea longiscata* Brong., and *Viviparus lentus* (J. Sow.). Seed-vessels of plants (*Carpolithes*, *Lymnocarpus*) are exceedingly common. The marly beds with *Limnaea* (11 to 13) appear to thin

out eastward, as a trial-pit opened at Paddy's Gap showed the marine Middle Headon in contact with the sands of the Unio Beds (*see below*, p. 45).

The Lower Headon probably is thicker about Hordle than in any other part of the Lymington district. To the east and north-east, the vertical interval between the Barton Sands and the Middle Headon decreases—albeit in an irregular manner—leaving room, in some places, for barely 15 feet of the Lower fresh-water series. In the Isle of Wight, too, the Lower Headon becomes thinner towards the east. There is no evidence of a lateral passage of these brackish and fresh-water beds into the marine series. On the contrary, at Whitecliff Bay, and in the few localities on the mainland where the junction of the Lower and Middle Headon has been clearly seen, the latter rests on an eroded surface; and the existence of a slight unconformity at the contact is further indicated by the overlapping of the lower beds of the Middle Headon by the higher, to be noticed on a later page. But while there is some reason to think that the thinning of the Lower Headon is accompanied by the loss of its higher members, the strata comprised in that series are individually so variable that it is impossible to say how far erosion in Middle Headon times was responsible for the changes observable in their aggregate thickness.

Other Exposures.—The Lower Headon Beds have been dug for marling land, brick-making, and other purposes in a great many places, but at present nearly all the workings are disused and overgrown.

The black lignitic loams at the base are well shown in the upper part of the sandpit on Barton Common, and were recognised by the Officers of the Geological Survey in road and railway cuttings that cross the boundary of these beds at Sway, Durns Town, and to the west of Brockenhurst Junction. In a well at the Water Works close to Milton Station the junction with the Barton Sands was reached at a depth of 121½ feet from the surface.[1] The presence of *Cerithium* and *Cyrena* is noted at 28 feet, and of shell-beds farther down, but it is not clear whether the beds classed as Headon belong entirely to the Lower Series, or partly to the Middle.

Green clays with *Erodona plana* (J. Sow.), *Cyrena obtusa* Forbes, and other brackish-water shells can be seen in a brickyard by the Danes Stream south-west of Hordle; also in road-banks and ditches at Brown Hill south of Holmesley Station, and in Wootton Copse and Broadley Inclosure south of Wilverley Walk. Fresh-water shell-beds were exposed on the opening of the shallow railway-cuttings at Great Arnewood, Sway, and Durns Town. Near Brockenhurst Junction, and at Sandy Down north of Boldre, the Lower Headon seems to be about 30 feet thick, while at Lady Cross Lodge, according to the data given in the well-record already referred to (p. 37), it is not more than 15 feet thick, and may be even less.

A thin representative of the basal lignitic beds appears beneath

[1] 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, p. 106.

the Plateau Gravel at the top of the sandpit a quarter of a mile south-west of Walhampton House, and was formerly well shown, with about 18 feet of the overlying beds, in the large brickyard east of the Buckland road in the northern part of Lymington. At the latter spot Mr. C. Reid noted the following section, in 1892:—

		Feet.
Plateau Gravel	... ...	8
Lower Headon Beds.	Sandy loam	1
	Light green clay	1
	Green clay with bones of turtle ...	3
	Irregular ferruginous sandy seam ...	0½
	Green clay	6
	Carbonaceous sandy clay	2½
	Grey loam with ferruginous joints ...	2½
	Greenish and ferruginous clay	0⅔
	Light grey clay	1
	Black seam	0½
Barton Sands; buff sands worked to more than...		22

The "green clay with bones of turtle" most probably represents the Mammalia Bed of Hordwell Cliff section.[1]

Continuing eastward, mottled green and red clays appear from beneath the Plateau Gravel along the shore of the Solent between the mouth of Lymington River and Stone Point. They have yielded *Cyrena obovata* (J. Sow.), *Melania acuta* (J. Sow.), *Viviparus lentus* (J. Sow.), *Planorbis euomphalus* J. Sow., and other common molluscs in small exposures east of Tanner's Lane, and in the old brickyard at Pitt's Deep, where shells abound in blue and green marly clays. At the Solent and Exbury Brickworks (also disused) remains of *Diplocynodon*, *Ocadia*, and *Trionyx* have been found in green clays which may be on the horizon of the Crocodile Bed. Inland, the Middle and Upper Headon Beds occupy much of the ground about Beaulieu Heath and Langley, but some green clays and marls with *Cyrena*, *Viviparus*, and *Melania*, shown in old workings on the sides of the Plummers Water valley, between Fortmore Common and Norleywood, may belong to the Lower division.

Middle Headon.

This is one of the most interesting of the local Tertiary stages, and, unfortunately, among the least clearly exposed. Much of the available information as to its facies in the Lymington district was collected in railway and other temporary sections, many years ago.

The Middle Headon of the Hampshire mainland is divisible into three sub-stages, which Messrs. H. Keeping and E. B. Tawney[2] distinguish as the—

3. Venus Bed or *Mœretrix incrassata* ("*Cytherea*") Zone,

[1] G. Mantell mentions finding "several vertebrae and dermal bones of a crocodile," as well as remains of turtle, in a brickyard east of the river at Lymington. 'Geology of the Isle of Wight,' 1847, p. 163.

[2] 'On the Beds at Headon Hill and Colwell Bay, &c.,' *Quart. Journ. Geol. Soc.*, vol. xxxvii, 1881, pp. 113, 114.

2. *Voluta geminata* (or Roydon) Zone,
1. *Voluta suturalis* (or Brockenhurst) Zone;
numbers (1) and (2) comprising what are known as the "Brockenhurst Beds." The Middle Headon Beds will here be briefly described under the headings of these three zones, beginning with the lowest.

1. *Zone of Voluta suturalis.*—The type section was that exhibited in the cutting on the Dorchester Branch Railway through Whitley Ridge Walk, north-east of Brockenhurst. The zone there consists of sandy clay, from a few inches to one foot thick, resting on an uneven surface of the Lower Headon Beds. It is rich in remains of the most purely marine fauna observed in the British Oligocene.[1] A remarkable feature is the prevalence of small corals, which have been referred to about 15 species, including—*Solenastraea cellulosa* Dunc., *Balanophyllia granulata* Dunc., *Lobopsammia cariosa* Goldf., *Axopora michelini* Dunc., *Madrepora anglica* Dunc., *&c.* Among the mollusca are *Psammobia compressa* var. *arcuata* Edw. MS. (*Psammotaea*), *Meretrix deltoidea* var. *attenuata* Edw. MS., *Cardita deltoidea* (J. Sow.), *Pecten bellicostatus* S. V. Wood, *Pisania labiata* J. de C. Sow., *Pleurotoma transversaria* Lam., *P. cymaea* Edw., *Voluta suturalis* var. *contabulata* Edw. MS.

Whitley Ridge would appear to be the only spot in the Lymington district at which this zone has been observed; but so thin a bed may easily be overlooked, and, as far as the eastern part of the area is concerned, the failure to detect it may be accounted for by a lack or scarcity of openings. The fact that the zone has been identified at places as far apart as Lyndhurst on the north and Whitecliff Bay on the south-east suggests that it has, or originally had, a wide extension. To the west, however, this zone is overlapped by newer beds: it is reported to be absent from the base of the Middle Headon in the brickyard section at Royden (*see below*), and in a temporary excavation at Paddy's Gap near Hordle House; and no trace of it has yet been found in the cliff-sections at the western end of the Isle of Wight.

2. *The Zone of Voluta geminata,* which includes the bulk of the "Brockenhurst Beds," is composed of alternating bands of sandy clay and loamy sand. Fossils abound in the upper part of the zone. The molluscan fauna has much in common with that of the *V. suturalis* Zone, the chief points of distinction being the abundance of *Voluta geminata* J. de C. Sow., and the absence or rarity of *Voluta suturalis*, *Pleurotoma cymaea*, and *Meretrix attenuata* (*Cytherea solandri* J. Sow.). Corals, too, seem to be much less common than in the lower zone; they certainly are so at Whitecliff Bay.

Till recently a good section was to be seen in the brickyard east of Royden (or Roydon) Farm, where at times both the upper and

[1] *See* A. von Koenen, 'On the Correlation of the Oligocene Deposits of Belgium, Northern Germany, and the South of England,' *Quart. Journ Geol. Soc.*, vol. xx, 1864, p. 97. *Also* Keeping and Tawney, *op. cit.*, pp. 109–114. G. F. Dollfus contends that the Headon Beds are of Upper Eocene (Marinesian) age: 'On the Classification of the Beds of the Paris Basin,' *Proc. Geol. Assoc.*, vol. xxi, 1909, pp. 107–111.

lower limits of the Middle Headon were exposed. The sequence here made out by Messrs. Keeping and Tawney, in the course of observations extending over a period of many years down to 1883, is shown in the following table.[1]

SECTION AT ROYDEN BRICKYARD.

		Ft.
Plateau Gravel, wash from		1
Upper Headon Beds	Clays and sands with layers of *Erodona*, *Viviparus*, and *Cyrena*. A band of *Erodona plana* in clay iron-ore near the top	7
Middle Headon Beds, 18½ ft. ?[2] — Zone of *Meretrix incrassata*	Bluish to yellow clay (2–3 ft.), resting on a clayey shed-bed (9 in.) . . . . seen for about ... ... Fossils.—*Meretrix incrassata* (J. Sow.), *Cyrena obovata* var. *subtriangularis* Edw. MS., *Cardita oblonga* var. *transversa* S. V. Wood, *Trigonocoelia deltoidea* (Lam.), *Ostrea velata* S. V. Wood, *Pisania labiata* (J. de C. Sow.), *Murex sexdentatus* J. de C. Sow.	4
Middle Headon Beds, 18½ ft. ?[2] — Zone of *Voluta geminata*	Grey clay resting on two nodule-bands of iron-ore septaria, separated by grey sandy clay. Stiff bluish clay (2 ft.) at base ... ... Fossils.—*Psammotaea aesturina* Edw. MS., *Meretrix suborbicularis* Edw. MS., *Protocardium hantoniense* Edw. MS., *Corbula pisum* J. Sow., *Voluta geminata* J. de C. Sow., *V. spinosa* (Linn.), *Strepsidura armata* J. de C. Sow., *Pleurotoma transversaria* Lam., *P. hantoniensis* Edw., *Natica epiglottina* Lam., *&c.*	7½
	Greenish-grey clayey sand	7
Lower Headon Beds—Clays, freshwater; *Unio solandri* J. de C. Sow.		—

Except for a few poor exposures of the blue clay at the top of the Middle Headon, and of the shelly bed with ironstone above, the section is now obscured. Remains of a whale, *Balaenoptera? juddi* Seeley, were found in one of the Middle Headon Beds.

Messrs. Keeping and Tawney remark that the *Voluta geminata* Zone, which has here apparently overlapped the Zone of *Voluta suturalis*, thins out in its turn a little farther west. It occurs near Lyndhurst, to the north, but not in the nearer locality of Whitley Ridge cutting, though *Voluta geminata* and *Pleurotoma hantoniensis* are recorded from the well-boring at Lady Cross Lodge, barely half a mile away. At Beaulieu, to the east, the characteristic volute was found in the river-banks south of the village by Prof. J. W. Judd,[3] who also observed some indications of the Brockenhurst Series in the Darkwater Valley, near Langley. In the Isle of Wight this zone is absent from the cliff-sections on

[1] Based on that of Keeping and Tawney, *op. cit.*, p. 113, supplemented by information published by E. B. Tawney in a later paper, 'On the Outcrop of the Brockenhurst Beds near Lyndhurst,' *Geol. Mag.*, 1883, p. 160.

[2] J. W. Judd (*Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 478) states that the thickness of the "Brockenhurst Series" at Royden "certainly exceeds 25 feet."

[3] 'On the Relations of the Eocene and Oligocene Strata in the Hampshire Basin,' *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 478.

the west, but *Voluta geminata* and a few other shells common at Royden were met with in a well at West Cowes,[1] and at the time of writing the zone is clearly exposed at Whitecliff Bay—now probably the only spot where it can be readily examined.

3. *Zone of Meretrix incrassata.*—On the Hampshire mainland the marine clays and loams which succeed the Brockenhurst Beds seem to represent, not merely the "Venus Bed," but the whole of the Middle Headon, of the Headon Hill and Colwell Bay sections in the Isle of Wight.[2] The data available are, however, so scanty that the writer thinks it best to adhere to the classification employed by Messrs. Keeping and Tawney,[3] and to deal with the remainder of the Middle Headon under the above zonal heading.

In the Lymington district, the shelly clays and loams of the *Meretrix incrassata* Zone are persistent, and, indeed, almost co-extensive geographically with the Middle division of the Headon Beds. The westernmost point at which they have been observed is Paddy's Gap, south-east of Hordle House, but what is known of the structure of the country suggests that they extend a little farther in the neighbourhood of Hordle village.

At Paddy's Gap a trial-pit, opened by Messrs. H. Keeping and J. W. Elwes in 1883, with the object of settling a tiresome controversy concerning the position of the marine Headon Beds in the Hordle Cliff section, revealed the following descending sequence:—

SECTION AT PADDY'S GAP.[4]

		Feet.
Soil		1
Plateau Gravel, ironstained at base		2½
Middle Headon	Whitish sand	1–1½
	Marine bed: sand and comminuted shells, chiefly of small estuarine and marine species, including *Cyrena obovata* (J. Sow.), *C. pulchra* (J. de C. Sow.), *Meretrix incrassata* (J. Sow.), *Ostrea velata* S. V. Wood, *Pisania labiata* (J. de C. Sow.), *Murex sexdentatus* J. de C. Sow., *Melania acuta* (J. Sow.), *Cancellaria elongata* Nyst, *Scala laevis* (Morr.), *Neritina aperta* (J. de C. Sow.), *N. concava* J. de C. Sow., *Potamides vagus* (Sol.), *P. ventricosus* J. Sow.	
Lower Headon	Light bluish-green clayey sand with *Viviparus* and *Unio*.	

As far as it is recorded, the fauna of the Middle Headon here is that of the Neritina Bed of the western part of the Isle of Wight: the most characteristic species of the Brockenhurst Beds are absent.

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[1] 'Geology of the Isle of Wight,' *Mem. Geol. Surv.*, 2nd ed., 1889, pp. 140, 141.

[2] T. Leighton (*Proc. Geol. Assoc.*, vol. xii, 1891, p. 152) suggests that the Brockenhurst Beds are the deep-water equivalent of the lowest ('Neritina') beds of the marine series at Colwell Bay, on the ground that, in the western part of the Isle of Wight, there is no direct evidence of a break between the Lower and Middle Headon, such as occurs elsewhere.

[3] *Op. cit.*, pp. 113, 114.

[4] Based on J. W. Elwes's paper, 'The Middle Headon Marine Bed at Hordwell,' *Geol. Mag.*, 1883, pp. 527, 528.

There is evidence, in fallen material, that the Middle Headon occurs in the upper part of the cliff nearer Milford, and clay with *Meretrix incrassata* was noted by Mr. Clement Reid at Woodend, near the coast south of Lymington. Farther east, older beds are brought up by the anticlinal flexure mentioned on p. 7; and beyond the mouth of Lymington River nothing more is seen of the Middle Headon along the northern shore of the Solent.

Inland, Mr. Reid, when re-surveying the district in 1892, observed many small exposures of shelly clay and loam rich in *Meretrix*, often accompanied by such other forms as *Cyrena obovata* (J. Sow.), *Ostreae*, *Cardita*, *Corbula cuspidata* J. Sow., *Pisania labiata* (J. Sow.) and *Melania acuta* (J. Sow.) (=*M. muricata* S. V. Wood). These exposures—in ditches, road-banks, and degraded marl-pits—are generally poor, and of little interest except as evidence of the extent of country occupied by the beds. The marine clays can be seen, more or less distinctly, in old workings on the western side of the railway at Widden Bottom; by milestone "15" on the Brockenhurst-Lymington road on Setley Plain; by the road-fork on that Plain a quarter of a mile east of Brockenhurst Junction; and in Perry Wood Inclosure north-west of Victoria Tile Yard, Brockenhurst. They were formerly visible in the Whitley Ridge railway-cutting near the bridge north of Lady Cross Lodge, and have been observed in the northern part of Frame Heath Inclosure.

The section at Royden Brickyard has already been described (p. 44). South of this, green and brown clays with *Meretrix incrassata* have been worked by the road-side on the 50-feet contour on the south-eastern slope of Sandy Down, and can be seen in the bottom of the combe north-west of Slade.

The marine beds were traversed in the well-boring at Lady Cross Lodge, where *Meretrix incrassata* and *Ostrea vectensis* (? *velata* S. V. Wood) were found respectively 15 and 20 feet above the top of the Barton Sands (*see above*, p. 37). Other fossils recorded, but without particulars as to depth, include a *Cardita*, *Voluta geminata*, *Pleuratoma hantoniensis*, and *Cerithium concavum* (=*Batillaria concava* (J. Sow.)).

Near Beaulieu there are small exposures of marine shell-beds low down on the wooded slopes above the left bank of the river in Oxleys and Spearbed Copses. Upwards of 60 years ago the late J. C. Moore, who was the first to call attention to the occurrence of Headon Beds in that part of the district, noted the following succession in a brick-yard (long since overgrown) on the eastern side of the river at Beaulieu[1]:—

	Feet.
Soil and diluvium: brown clay	2
Sandy clay, containing two seams of shells, 1 foot apart: the upper with *Cyrena obovata*, *Melania costata* (*Turbonilla*), *Cytherea incrassata* (*Meretrix*), and *Ostrea* ...	3 to 4
Yellow and light-coloured sand	—

The same author mentions two exposures of greenish marl with

[1] 'Notes on the Occurrence of Eocene Freshwater Shells at Beaulieu, Langley, &c.,' *Quart. Journ. Geol. Soc.*, vol. v, 1849, p. 316.

Cytherea in the valley of the Dark Water, or of its western branch (the Stock Water), "near Langley." The account he gives of one of these sections suggests that it showed part of the Upper, as well as of the Middle, Headon; the descending sequence being—

Diluvium: ferruginous clay	2 or 3 inches
Greenish clay with vegetable impressions; stiff clay without fossils	6 or 7 feet
Beds of nodules of ferruginous clay, containing casts of *Limnaea longiscata*, *Melania costata*, a *Natica*, *Cyrena*?, and a *Nucula*?	
The lowest bed seen was a greenish marl with perfect *Cytherea incrassata*.	

Upper Headon.

Very little is known about the stratigraphy of this division on the Hampshire mainland. The lithological facies is generally similar to that of the Lower Headon; bands of green and dull reddish clay or marl alternating with loamy sands, occasional seams of limestone, and layers of closely-packed shells. The fauna, as far as can be seen, is mainly of fresh-water character.

On the west, these beds make their first observed appearance in a small outlier beneath the Plateau Gravel about Setley. Their main-mass underlies Beaulieu Heath, and one or more other outliers probably occur to the east of Beaulieu River.

A road-side pit on the end of the spur of Setley Plain east of Royden Farm shows a few feet of laminated greenish loam and yellow sand beneath Plateau Gravel. These beds are well above the base of the Upper Headon, which runs through the higher part of the pits at Royden Brickyard, at a level just 50 feet lower. The *Erodona*-clays with *Cyrena obovata* (J. Sow.), *Viviparus lentus* (J. Sow.), *Potamides vagus?* (Sol.), *&c.*, and thin band of shelly iron-ore, observed by E. B. Tawney[1] about 1883, and noticed on another page (44) of this memoir, can still be distinguished in the brickyard, and in the banks of the road to the south.

In the higher ground of Beaulieu Heath, immediately to the east, there should be room for more than 100 feet of newer beds; and probably at least that thickness of the marls, shell-beds, and thin earthy limestone (1 foot) proved in the well at Lady Cross Lodge belong to the Upper Headon.

Farther east, coloured clays—occasionally holding ill-preserved shells—appear here and there along the courses of the brooks on Beaulieu Heath; also in the sides of the Beaulieu Valley. The exposures noted were of little interest, but it may be mentioned that remains of fish and turtle were found by Mr. Reid, in grey clay with marly seams, in an old pit within the north-western angle of Keeping Copse near Beaufre, at a level about 70 feet higher than that at which the *Meretrix incrassata* Beds are seen on the opposite side of the Beaulieu Valley.

[1] *Geol. Mag.*, 1883, p. 160.

CHAPTER IX.

PLEISTOCENE BEDS.

Between the Headon Series and the oldest local deposits of Pleistocene age there is a wide stratigraphical gap, which the Osborne, Bembridge, and Hamstead Beds of the Isle of Wight, once, no doubt, represented on the Hampshire mainland, go but a little way towards filling.

During the lapse of time implied by this hiatus physical changes of considerable importance took place. The southern part of the English region, previously an area of depression and deposition, was raised into land; its strata were compressed into a series of folds, and the topographic relief resulting from these movements was reduced by erosion to something approaching its present proportions.

The compound syncline of the Hampshire Basin, defined during this period, has long since been marked by an area of comparatively low ground; the weakness of the infolded Tertiary beds under erosion tending to maintain a feature that may have been purely tectonic in the beginning. Though now open to the English Channel, and, indeed, largely covered by its waters, this lowland was formerly bordered on the south (as it still is on the west and north) by higher ground of anticlinal structure, remains of which survive in the Isle of Purbeck and the Isle of Wight.

The eastern part of the Hampshire Basin mostly lies off the coast of Sussex, and earlier phases of its geomorphic evolution can therefore only be conjectured. The western part, however, is more open to observation, and here there is not much doubt that the inward drainage of the enclosing uplands for a long time was carried eastward by a trunk-stream which followed a course approximately marked by a line drawn through Poole Harbour, Christchurch Bay, the Solent, and Spithead.[1] That ancient "River Solent" seems to have persisted well into Pleistocene times, and there is reason to think that the capital disintegration of its system, which followed upon the effective breaching of the southern uplands, and the interception of the main stream by the sea westward of the Isle of Wight, took place mainly within the period covered by the deposition of the superficial formations now to be considered.[2]

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[1] The subject has been discussed by many writers. *See* A. Strahan, 'Geology of the Isle of Purbeck,' *Mem. Geol. Surv.*, 1898, pp. 230–235, and C. Reid, 'Country around Ringwood,' *Mem. Geol. Surv.*, 1902, pp. 31, 32; and references in those works.

[2] A study of the contours of the area formerly drained by the Solent River affords no satisfactory evidence as to the particular stage in the development of the existing physiography of that region at which the upper reaches of the river were severed from the lower by the encroachment of the sea between the Isle of Purbeck and the Isle of Wight. It may be that, at the time this event occurred, the level of the River Solent at the point of diversion differed little from that

Gravels and Brickearth.

As a glance at Sheet 330 will show, gravels of the Plateau group occupy much of the inter-stream spaces in the southern part of the New Forest. From the ridges of Barton Sand, above 200 feet O.D., near Rhinefield Walk, they extend south and eastward over the broad flats on the Headon Beds about Lymington and Beaulieu, and pass beneath Recent deposits at sea-level on the shore of the Solent; the relative positions of the several spreads being such as to suggest that they are parts of a once-continuous sheet.

Well stratified on the whole, and frequently current-bedded; consisting largely of subangular stones, and yielding numerous palaeoliths of Chellean and Acheulian types, the Plateau gravels about Lymington differ in no important respect from deposits elsewhere which are confidently ascribed to river-action; and although, from what is seen in the country to the east, there is reason to think that the sea may have had a share in the planing-down of the Tertiary Beds on which they rest, the essentially fluvial origin of the gravels themselves appears to be hardly open to question.

The occurrence of silicified Purbeck limestone, radiolarian chert, and veined quartzite, among the flints, Cretaceous cherty sandstone, and quartz-pebbles which form the bulk of the gravel, points to a derivation of material from distant sources to the west and north-west, and is in accordance with the view that the deposits around Lymington are the work of one or more streams belonging to the Solent River system, if not of the Solent River itself. Older gravel-strewn terranes in the northern part of the New Forest area also probably contributed much material of all kinds, along lines of drainage having the same trend as the Lymington and Beaulieu Rivers. At the epoch of the Plateau Gravel and modern brooks can have had no separate existence, for the structure and disposition of the gravel imply that the greater part of the district was then overrun by shifting channels, fed by a volume of water greatly exceeding that carried by the local streams at the present day.

Although the gentle decline of the sheets of gravel towards the Solent is uninterrupted by sharp changes of gradient, it is inferred from phenomena presented in adjacent areas that two or more drift-stages, elsewhere distinct, are here merged in one. To the west and north-west, as Mr. Clement Reid has shown,[1] the Plateau gravel is resolved into a series of terraces, ranging along the sides of the wide valley of the Salisbury Avon, and rising

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of the sea (*cf.*, Strahan, *Proc. Geol. Assoc.*, vol. xiv, 1896, p. 407); in which case the directly resulting change in the gradient of the river and of its tributaries, both above and below this point, would have been too slight to make such an impression on the topography of the Solent River basin as could be recognised after a lapse of some thousands of years. Having regard to the general condition of the dismembered parts of the Solent River system, and to the present rate of erosion of the cliffs of Christchurch Bay, the writer is not prepared to refer the diversion of the upper (or Frome) section of the river to so remote an epoch as that implied by Mr. C. Reid in his memoir on the country around Ringwood (pp. 31, 32, 34).

[1] 'Country around Ringwood,' *Mem. Geol. Surv.*, 1902, pp. 33-45.

towards the source of that river. There is a roughly parallel partition on the north and north-east, but in these directions the Plateau Gravel of the southern slopes of the New Forest is represented, not only by river-terraces in the valleys of the Test, Itchen, and Meon, but also (to the north-east) by two raised marine platforms, which follow the coast into Sussex. These latter features are distinguished in the memoir on the Fareham district as the upper and lower platforms of the coastal plain.[1] They both slope, on the whole, gently seaward; the upper platform, which includes the raised beach of Goodwood and Avisford, from about 140 to 100 feet O.D.; the lower, including the raised beach of Worthing and Brighton, from about 50 feet O.D. to below sea-level. The degraded bluff between them, though plainly marked in the area of the Fareham map-sheet (No. 316), is not discernible in the Lymington district, or only doubtfully so, as in the slope south of Fawley.

The lower platform takes in all the mainland shown on the Portsmouth Sheet (*see* fig. 2,[2] p. 6). The deposits which cover it here and in the Selsey peninsula are of varied types, and appear to differ considerably in age; but as the lower of them have a sporadic distribution, and are seldom well exposed, some doubt exists as to their true sequence.

According to Mr. Clement Reid,[3] who fortunately saw the critical sections opened on the shore of Bracklesham Bay by the autumnal gales of 1891, the oldest of the local Pleistocene beds so far known is a gravel (apparently of trifling thickness) containing erratic boulders, the majority of which are composed of Tertiary and Cretaceous rocks, such as crop out on the coast of Sussex and the Isle of Wight; and the remainder of igneous and metamorphic rocks, comparable with those forming the southern and north-western shores of the English Channel. The presence of these erratics is ascribed to the stranding of drift-ice upon an ancient fore-shore, at a time when the sea-level was a few feet higher than at present. Grooves and striae, strongly suggestive of ice-action, have been observed on a boulder of Bognor Rock; and in many cases the erratics and masses of the associated gravel indent, and deflect the bedding of, the underlying Eocene clays, as if pressed down by the weight of an ice-foot. Several erratics thus embedded were observed by Mr. Reid near West Wittering, and there is good reason to believe that others occur in a like position at the southern end of Thorney Island, but the most important exposure of erratic gravel was that presented on the shore by Medmerry Farm, beyond the eastern boundary of the area covered by this memoir.

The Erratic Gravel occurs in patches, as if eroded, and it is doubtful how far north of the present coast-line the deposit extends. Boulders, presumably derived from it, are common on

[1] Pp. 72, 80. *See also* T. Codrington, 'On the Superficial Deposits of the South of Hampshire, &c.,' *Quart. Journ. Geol. Soc.*, vol. xxvi, 1870, pp. 533, 534, and Plate xxxvii.

[2] The upper platform is not discernible on this line of section.

[3] 'The Pleistocene Deposits of the Sussex Coast, &c.,' *Quart. Journ. Geol. Soc.*, vol. xlviii, 1892, pp. 344–361.

the shores eastward of Portsmouth. Others are met with inland, as way-side blocks and, occasionally, as inclusions in superficial deposits which are indubitably younger than the Erratic Gravel of the Medmerry Farm section. Leaving out of account the ubiquitous blocks of Tertiary sandstone known as sarsens or grey-wethers, these residual boulders, in the Portsmouth district, appear not to range farther north than a line drawn through Lee-on-Solent, Landport, and West Thorney—which line may mark approximately the original limit of the Erratic Gravel in that direction.

Another member of the Pleistocene Series on this platform is the well-known Mud Deposit of Selsey. Though not yet observed in superposition, it is inferred on internal evidence to be younger than the Erratic Gravel. Boulders are not wanting in the Mud Deposit itself, but, inasmuch as the latter is characterised, in its lower part, by a rich marine fauna which clearly shows "the influence of warmer seas than those which now wash our shores"; and in its upper part by a brackish-water fauna and terrestrial flora both indicative of temperate conditions, Mr. Reid is justified in describing these included erratics as "redeposited," with the implication that their redeposition was effected without the aid of drift-ice.[1]

The Mud Deposit, usually to be seen on the shore near Thorney Farm (Sheet 332), is not known to extend into the Portsmouth district. Its upper parts, however, may be represented by the fossiliferous estuarine and freshwater beds which occupy a buried river-channel near West Wittering, and by similar beds at Stone Point in the Lymington district. These latter two deposits are dealt with more particularly below, in the notes of exposures.

There is no doubt about the chronological order of the next three divisions of the Pleistocene Series. In the coast-sections mentioned above the Erratic Gravel, the Mud Deposit, and the estuarine beds of West Wittering, are each immediately overlain by the shingle and sand of a raised beach; while the shingle in its turn is largely covered, there and elsewhere, by the Combe (or Coombe) Rock, which passes into the overlapping low-level Brick-earth.

The shingle most probably is of about the same age as the similar raised-beach deposits of Worthing and Brighton, which contain shells of littoral species common in the English Channel at the present day. Following, as it does, upon the estuarine beds of Selsey and West Wittering, it may be taken to indicate a positive displacement of the sea-level, and a concomitant northward shifting of the littoral zone. Yet, in the comparatively short interval of time between the accumulation of the beach-shingle and its burial by the ensuing deposit, there must have been a reversal of these movements, for the Combe Rock is a sub-aerial formation, whose original limit seaward lay somewhere to the south of the existing shore-line. Spread out on the coastal

[1] *See* C. Reid, *op. cit.*, pp. 355, 356; *also* 'Notes on a Post-Tertiary Deposit in Sussex,' *Yorks. Phil. Soc. Report for 1892*, 1893, pp. 69, 72, by A. Bell, who contends that the Erratic Gravel is newer than the Mud Deposit.

plain, it is believed, in a number of confluent fans, by the torrential run-off of rain falling on a frozen surface of the Chalk farther inland,[1] the Combe Rock and intimately associated Brickearth mark the recurrence of an age of low temperatures—apparently the penultimate cold phase of the Pleistocene, as far as the South of England is concerned.

It is difficult to establish a satisfactory correlation between the deposits noticed above and the low-level Plateau Gravel, on the same platform, about Portsmouth, Alverstoke, and Lee-on-Solent. The latter resembles the Plateau Gravel of the Lymington district, in that it is generally well stratified, is mostly of fluvial aspect, and yields palaeoliths of Acheulian forms. On the other hand, it is allied to the deposits about Wittering and Selsey by the presence of far-travelled erratics (which, however, become rare westward of Portsmouth), and of occasional intercalations of wave-worn shingle; while in places the upper parts of it are hardly distinguishable from Combe Rock of the loamy type which prevails in the country east of Portsmouth. Probably it embodies deposits of divers ages, though the greater part of it may well be contemporary with the raised-beach shingle and sand of Selsey.

One other division of the superficial strata remains to be noticed in this chapter, namely, that distinguished on Sheets 330 and 331 as "Gravel Terraces." This term is applied to certain old river-deposits, and the wash therefrom, such as are usually classified as Valley Gravel in other publications of the Geological Survey. In the mainland area dealt with in the present work the deposits in question are almost confined to the environs of Brockenhurst, where some of them cover, and help in varying degrees to form, small terraces on the sides of the valleys. In their composition, and, as far as can be seen, in their structure also, they resemble the adjacent Plateau Gravel, whence their coarser constituents are derived. No information can be given here concerning the age of these terrace-gravels, save that their low-lying portions, near the streams, are probably of about the same age as the Combe Rock.

Notes of Exposures.

1. Lymington District.

a. *Plateau Gravel and Brickearth.*—Gravel-sections are so plentiful in this part of the country that it is not practicable to notice more than a small selection in these pages. Beginning on the west—

Clear exposures of stratified, coarse, sandy gravel, cemented in places by iron-oxide, are presented in the upper part of Barton and Hordle Cliffs. The thickness now visible ranges up to about 25 feet, but it is recorded that in former years, when the cliffs stood perhaps 100 to 150 yards seaward of their present position, the thickness was twice or thrice as great.[2] Palaeo-

[1] C. Reid, 'On the Origin of Dry Chalk Valleys and of Coombe Rock,' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, pp. 364–371.

[2] *See* T. Codrington, 'On the Superficial Deposits of the South of Hampshire, &c.,' *Quart. Journ. Geol. Soc.*, vol. xxvi, 1870, p. 532.

lithic tools—some of Upper Greensand chert—have been found in large numbers along the coast between Barton and Milton.[1]

Inland from Barton Cliff the gravel thins to about 10 feet, and is exposed in several pits around Hordle and Bashley. Small sarsens are not uncommon. When the railway cuttings north-east of Milton were opened the Headon Beds beneath the gravel were observed to be puckered and contorted in many places.

About Milton and Tiptoe the gravel is covered by a coarse loam, 1 to 5 feet thick, which can be seen in an old brickyard south of Milton Station. The loam contains seams of small stones, and probably differs little in age from the gravel below.

There are several road-side pits on the ridge of Wilverley Inclosure. At Shoot Wood and Markway Hill, on the northern border of the spread covering this ridge, the gravel is concreted by iron-oxide into a firm pudding-stone, known locally as "Burley Rock," after the neighbouring village.

On the Plateau east of Durns Town much of the gravel is bleached to a chalky whiteness, the pieces of chert in it being not less affected than the flints.

In the good sections west of Royden Farm; by the cross-roads west of Sandy Down; and in the brickyard in the northern part of Lymington, the gravel, 8 to 10 feet or more thick, is sandy and well-bedded; but in the extensive workings a quarter of a mile east of Brockenhurst Junction the structure is confused, and there are large inclusions of loamy matter. The workings last mentioned are situated on the border of the Setley Plain gravel-spread, which has yielded some palaeoliths. Mr. Reginald A. Smith has lately figured a pointed implement (*ficron*) of the Chelles stage from this locality.[2]

East of Lymington River, noteworthy sections of sandy, stratified gravel exist at Dilton Farm; on Bull Hill; at the eastern end of Hatchet Pond; and north-west of Thorns, near Sowley Pond. At Hilltop, east of Beaulieu, pits show similar gravel containing much cherty sandstone. Other good exposures are to be seen in Yard Wood, north-west of Exbury; on Blackfield Common and Hughs Common; and to the south of Fawley.

Along the Solent, from Keyhaven to Stone Point, gravel is seen in many places, but the shore-banks are low and afford few good sections. Beyond Stone Point, the coast, trending north-eastward, cuts into rather higher ground by Nelson's Place and Eaglehurst. Here the cliffs show 10 to 15 feet or so of ferruginous stratified gravel, resting unevenly on Barton Sands. A rough Palaeolithic "knife," made from a flint-flake, and possibly of Mousterian age, was found by Mr. Clement Reid near the base of the gravel east of Nelson's Place.[3]

On the foreshore, about one-third of a mile west of Stone Point, there is exposed an interesting mud-deposit of Pleistocene age, which has been described by Mr. Reid.[4] It consists mainly of stiff carbonaceous clay, and has yielded remains of elephant (*Elephas antiquus* ? Falc.), a few species of brackish and fresh-water shells (*Scrobicularia piperata* Belon., *Hydrobia similis* Drap., &c.), and 29 species of plants, including the South European maple (*Acer monspessulanum* Linn.), which, with the common oak, also represented, indicates a climate at least as mild as that prevailing on the Hampshire coast at the present day. This estuarine clay, which probably differs not greatly in age from the analogous mud-deposits of Selsey and Wittering, gives a clue to the stratigraphical position of the adjacent low-lying parts of the Plateau Gravel, beneath which it passes at the upper limit of the shore; just as the other estuarine muds alluded to pass beneath the raised-beach shingle and Combe Rock on the shore of Bracklesham Bay.

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[1] Sir J. Evans. 'Ancient Stone Implements,' 2nd ed., 1897, p. 637. Some specimens from this neighbourhood, and from Lymington, are in the British Museum collection, wall-case 102.

[2] 'Prehistoric Problems in Geology,' *Proc. Geol. Assoc.*, vol. xxvi, 1915, p. 7 and Pl. 1.

[3] C. Reid, 'A Fossiliferous Pleistocene Deposit at Stone, &c.,' *Quart. Journ. Geol. Soc.*, vol. xlix, 1893, p. 328, fig. 2.

[4] *Ibid*, p. 325.

b. *Gravel Terraces.*—Near Ober Farm, west of Brockenhurst, gravel thinly covers a terrace from 50 to 60 feet above the level of Lymington River at Brockenhurst Bridge. Smaller patches, showing terrace-features near Blackhamsley, are ranged along the course of Latchmoor Brook south-west of the village; and two others occur on the left bank of the Ober Water, in Aldridge Inclosure. The more extensive deposits about Butts and Balmer Lawns occupy sloping ground, which falls gently to the level of the Lymington River.

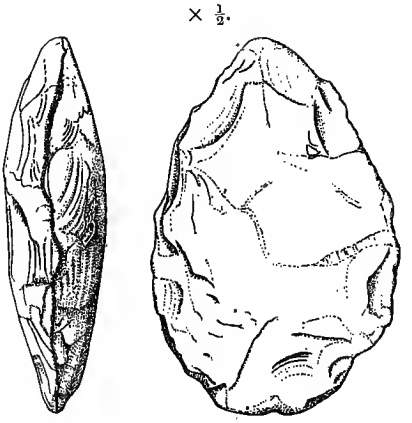
The only other example marked on the map is a small low-level spread north-west of the mill-pond at Beaulieu; but gravel appears in the banks of the stream at Royden and other places; and probably underlies much of the Alluvium in all the larger valleys.

2. Portsmouth District.

a. *Plateau Gravel.*—Good sections of the gravel and loam about Meon, Stubbington, and Rowner are presented in the cliffs along the Solent. The bevelled surface of the underlying Bracklesham Beds declines south-eastward, with a series of low undulations which alternately raise and depress the base of the gravel above and below high-water mark. The gravel—10 to 20 feet thick—

Fig. 10.—*Palaeolith of St. Acheul type, from the Plateau Gravel, Lee-on-Solent.*

× ½.



varies much in texture, and is frequently very coarse, with big, slightly-worn flints at the base. Bedding is plainly marked, and there are frequent lenses of roughly-laminated loam (fig. 6, p. 28).

At Hill Head and Stubbington Lane End the gravel is partly replaced by speckled loamy sand (derived from the Bracklesham Beds) with seams of bleached shingle, as well as of ordinary gravel. Sarsens are rather common in the lower part of the gravel all along the cliffs, and at Lee-on-Solent small rounded boulders of igneous rocks are occasionally to be seen in the same position.

Hill Head and Lee-on-Solent are well-known localities for Acheulian implements, which were first observed on the beach in 1863, and soon after traced to the gravel in the cliffs.[1] The *limande* sketched in Fig. 10 is

[1] *See* Sir J. Evans, *op. cit.*, p. 625.

typical of the implements from this part of the coast. It was found by the writer in fallen material at the foot of the cliff, 300 yards north-west of Lee-on-Solent pier.

Gravel with much interbedded light sand is exposed by the railway east of Lee-on-Solent, and a more ochreous gravel, varying much in thickness, can be seen in the banks of the creeks, as well as in fort-ditches and other artificial openings, at Alverstoke and Gosport.

On Portsea Island most of the ground occupied by the Plateau Gravel is now enclosed or built over. Records of excavations indicate that here also there is considerable variation in thickness, setting aside those doubtful cases in which Recent marine shingle may have been entered as "gravel." In the southern part of the island, gravel was formerly worked "near Southsea," in pits where it was "at least 27 feet thick," according to Mr. T. Codrington,[1] who records the occurrence in it of "numerous blocks of granite, syenite, and greenstone, as well as of sarsen-stone." He describes these blocks as "rounded and smoothed boulders, from 1 to 2 cubic feet in size," and brittle from partial decomposition. Similar boulders, sarsens, and large flint-nodules are occasionally found at the base of the Brickearth about Kingston and Buckland, in brickyards and trenches for the foundations of houses. A few tabular sarsens, from which the surrounding gravel and brickearth have been removed, are to be seen on the floor of an old working half a mile east of Baffins Pond. Palaeoliths have been found in the gravel at Southsea Common.[2]

East of Portsea Island, and beyond the boundary of the deposits mapped as Plateau Gravel, boulders of igneous and metamorphic rocks increase in number and size, while blocks of Upper Greensand, Bognor Rock, and Bembridge Limestone make their appearance.

On the shore of Langstone Harbour, west of the Manor House at South Hayling, there are upwards of a score of boulders, mostly of fine sandstone, but including dark hornblende-granite and biotite-gneiss. Other blocks—again mostly sandstone—are to be seen at and about South Hayling, on the sea-front and inland, where such stones were used in former times for building. There are good examples in the walls and yard of the parish church, and of the adjacent farm: many, too, have been collected in the grounds of Westfield House.[3] Sir Joseph Prestwich enumerates eleven kinds of rock represented in the Hayling erratics, including hard chalk drilled by annelids, and fossil wood from the Portland Beds. He states that the boulders "are often met with in trenching and draining, at a depth of from 1 to 4 feet," and "may vary in weight from ½ to 6 tons."[4]

Erratics of various foreign rocks—basalt, diorite, syenite, granite, gneiss, &c.—ranging up to about 5 feet in maximum diameter, and sarsens attaining greater dimensions, occur on the shore of Bracklesham Bay near Cakeham and East Wittering, and are occasionally to be seen in the low cliffs. Of the boulders north of the main coast-line in this part of the district, mention may be made of an exfoliating mass of pink granitoid rock, measuring roughly 6 × 5 × 3 feet, west of the hardway on the north side of Chichester Channel at Itchenor Ferry; and of a block of speckled grey rock, approximately 10¼ × 5½ × 4½ feet, on the foreshore of bare London Clay a quarter of a mile west of Longmere Point. The latter is the largest erratic of any sort now visible in the country covered by this memoir.[5] It shows signs of rapid disintegration along gaping fissures, and

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[1] *Op. cit.*, p. 353.

[2] J. Evans, *loc. cit.*, and A. W. Jamieson, *Proc. Geol. Soc.*, No. 947, 1913, p. 11.

[3] Lately re-named 'Château Blanc.'

[4] 'The Raised Beaches, and "Head" or Rubble-drift, of the South of England, &c.,' *Quart. Journ. Geol. Soc.*, vol. xlviii, 1892, p. 273.

[5] This boulder seems to have been not long exposed. Mr. Clement Reid, when surveying the Portsmouth district in 1891, noted down on the 6-inch field-map the positions of the boulders visible at that time, including some near Longmere Point; but he made no record of this one, nor, as he tells the

by its eastern end lie four detached masses (ranging up to 4½ feet in diameter) which, when in position, probably added another 1½ to 2 feet to the total length. Smaller pieces of the same sort of rock lie around the boulder, and others were noticed along the shore to the east.

Dr. H. H. Thomas contributes the following note on his petrographical examination of a specimen of the rock:—

> "E. 11220.—The specimen submitted has been sliced and proves to be a much-crushed Quartz-diorite. The rock has no similarity with anything in the south of England or Wales, except perhaps with some of the Pre-Cambrian Quartz-diorites of Pembrokeshire. Quartz-diorites are common in the Channel Islands and the North of France, and these localities would seem to furnish a more likely source than Pembrokeshire, especially as other boulders have been found on the South Coast, which, with good reason, have been considered to be of extra-British origin."—H. H. T."

The gravel of which this mass of diorite in all probability but lately formed a part, is well exposed in the adjacent cliff (fig. 11), and has much in common with the Erratic Gravel of the Medmerry-farm section, as described by Mr. Clement Reid and referred to above (p. 50). It is coarse in texture; contains much Bognor Rock and some small blocks of Bembridge

FIG. 11.—*Section near Longmere Point, West Thorney.*

Scale, 1 inch = 8 feet.

l. London Clay with septaria. Bedding disturbed.
g. Gravel with erratics.
b. Coombe Rock and Brickearth, stony loam.

Limestone, besides igneous rocks, quartzites, &c.; and occupies a group of basin-like indentations, 1 to 3 yards or more wide, in the London Clay. The indentations are clearly due to vertical pressure exerted by or through the contained masses of gravel, for the London Clay, which is well-stratified, has adapted itself to their shape by flexing and shearing, with a development of slickensides at and about the contact with the gravel. In many cases the gravel on the bottom and sides of the basins is cemented by tufa into a hard crust, 1 to 3 inches thick, which is apt to persist as a jagged ring on the shore for some time after the waves have cleared out the rest of the gravel and planed away the surrounding clay.

On the map, a little patch of the pink colouration indicative of Plateau Gravel, east of the entrance to Chichester Harbour, marks the position of the fossiliferous mud-deposit of West Wittering. The deposit crops out on the shore, and, like all the more interesting features of the Bracklesham-coast section, is liable to be

present writer, can he remember it. In May, 1914, it was 75 feet distant from the face of the cliff. The possibility of its having been carried to its present place by human agency (which has to be reckoned with in the case of most of the loose shore-boulders) seems to be excluded by its size and location.

hidden by accumulations of sand and shingle for months or even years at a time. It is at present (1914) quite obscured. The section laid bare by gales in 1891 is thus described by Mr. Reid:—

"To the west [of West Wittering Beacon] I found the stony loam, which overspreads the whole of the district, resting on an irregular surface of Eocene clay. The clay rose to above the level of high water, and at several spots erratic blocks were noticed embedded in pits or channels in its upper surface. A quarter of a mile to the south-west, shingle like that seen at Selsey comes in between the stony loam and the Eocene clay. Then, within a few yards, appear indications of an ancient eroded channel, and beneath the shingle is seen a series of freshwater and estuarine strata having a gravelly base full of re-deposited erratics. This channel cuts down into the Eocene clay to the level of low-water, but is only about ¼-mile wide. Eastward, however, appearances are most deceptive, for the more modern channel of an existing valley has cut through the Pleistocene deposits and breaks into the side of the older river-bed. One thus occasionally finds re-deposited bones of Elephant at the base of the later alluvium. . In the newer deposits bones of *Bos* are abundant, and the mollusca are all species common in the immediate neighbourhood at the present day. In the older series the bones belong to *Rhinoceros* and *Elephas*; *Corbicula fluminalis* is the most abundant shell, and *Succinea oblonga* and *Hydrobia marginata* are both common.

"The deposits in the older river channel are so irregular and thin that it would be difficult to give any but the most diagrammatic section of them. The general succession seen on the foreshore on the west side of the channel is:—

Laminated peaty clay, with *Corbicula, &c.*
Clayey gravel, with large flints, blocks of granite, &c.
Eocene Clay.

"A short distance to the east we find:—

Mass of rolled clay pebbles.
White marl with Chalk grains.
Clayey gravel with erratics.

"Still farther east the marl dies out, and peaty clay full of *Corbicula* comes on again. The deposits here described are seen on the foreshore, but the low cliff above shows that the old beach-shingle extends right across the channel, and is overlain by stony loam."[1]

The peaty clays above the gravel with erratics yielded bones of *Rhinoceros*, associated with land, freshwater, and a few marine shells; and seeds of plants. Mr. Reid records 94 species of plants,[2] which include several undetermined forms that belong to no living British plants, and two Mediterranean species, *Najas minor* Allione and *N. graminea* Delile, now extinct in Britain. The known mollusca comprise 8 marine and 62 non-marine species, the latter including *Corbicula fluminalis* (Müll.) and *Paludestrina marginata* (Mich.), also extinct in these islands. Besides the mammals already mentioned, remains of four other vertebrates have been met with, namely, water-vole (*Microtus amphibius* Linn.), frog (*Rana temporaria* Linn.), pike (*Esox lucius* Linn.), and eel (*Anguilla vulgaris* ? Turton).[3]

Mr. Reid observes that "the lower part of the deposit at West Wittering, though extending below the level of half-tides, is of purely freshwater origin; but the upper part of the loam contains many estuarine *Hydrobiae*, occasional cockles, and some salt-marsh plants. The incoming of marine

[1] 'The Pleistocene Deposits of the Sussex Coast, &c.,' *Quart. Journ. Geol. Soc.*, vol. xlviii, 1892, pp. 356, 357.

[2] 'Origin of the British Flora' (1899), pp. 94–96.

[3] J. P. Johnson, 'The Pleistocene Fauna of West Wittering,' *Proc. Geol. Assoc.*, vol. xvii, 1901, pp. 261–264. *See also* A. S. Kennard and B. B. Woodward, 'The Post-Pliocene Non-marine Mollusca of the South of England,' *ibid.*, p. 244, and Table opp. p. 268.

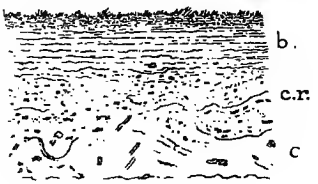
species would seem to indicate depression, and perhaps direct continuity with the marine shingle which overlies the fossiliferous deposit."[1]

b. The *Raised-beach Shingle*, not distinguished on the map, is much less developed in the Portsmouth district than in the neighbourhood of Selsey to the south-east. It appears in lenses and impersistent thin bands at the base of the Combe Rock and Brickearth in the cliffs near the Witterings and Bracklesham Farm; and there is evidence of its similar occurrence in the southern part of Hayling Island, where a few littoral shells are said to have been found.[2]

c. *Combe Rock and Brickearth.*—Combe Rock occurs over a greater area than one might infer from an inspection of Sheet 331, which shows only two little patches, a few acres in extent, at West Itchenor. It is mostly hidden by the low-level Brickearth, into which it shades both laterally and vertically, and is seldom to be seen away from the coast. Combe Rock is typically a rudely-bedded or structureless gravel, composed mainly of chalk

FIG. 12.—*Section on the eastern side of Bosham Channel.*

Scale, 1 inch = 8 feet.



c. Chalk. c.r. Combe Rock. b. Brickearth.

and unworn flints; but prolonged weathering converts it into a stony loam. In the levels east of Portsmouth the loamy facies is most in evidence; the calcareous constituents, where not entirely dissolved, usually occurring in the form of dirty tufaceous rubble in the lower part of the deposit.

Near Lowerhone Farm the eastern bank of Bosham Channel gives a fairly clear section, 7 feet deep, of confusedly-bedded flint gravel, passing downward into chalky rubble, and upward into brown loam with seams of stones (fig. 12).

The best exposures are on the coast of Bracklesham Bay, where red-brown stony loam, with a gravelly base, forms the upper 5 to 8 feet of the cliff. As a rule, the deposit rests unevenly on weathered Bracklesham Beds, but in places, as previously stated, remains of Raised Beach and older Pleistocene strata are intercalated. The same kind of deposit is seen above the gravel with erratics west of Longmere Point (fig. 11, p. 56), and in contact with the London Clay hard by.

Ironstained gravel crops out round the creeks on the eastern side of Hayling Island, near Fleet, but it thins westward, and on the shore of Langstone Harbour, north of Newtown, it appears only in impersistent bands lying between the Brickearth and the London Clay.

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[1] *Op. cit.*, *Quart. Journ. Geol. Soc.*, vol. xlviii, 1892, p. 359.
[2] Prestwich, *op. cit.*, p. 273.

The Brickearth covering most of the older beds in Portsea Island, for a depth of 1 to 7 feet, is comparatively free from gravel. In the brickyards near North End, where it rests on a slightly undulating surface of Reading Beds, the lower parts of the deposit are often suffused with the ruddy tint of the underlying mottled clay. South of Kingston and Copnor, the Brickearth overlaps and levels-up the inequalities in the surface of the Plateau Gravel. Their uneven junction was formerly well shown in the shallow railway cuttings between Fratton and East Southsea stations; and can still be seen in brickyards east of the road from Copnor to Eastney.

Mr. G. H. Thistleton-Dyer notes the occurrence of an ovate palaeolith, much water-worn, at "the base of the brickearth overlying the gravel in Southsea."[1]

Farther west the thin brickearths about Gosport are shown in disused brickyards at Elson and Privett; and those near Stubbington in yards south-west of Peel.

[1] In 'British Assoc. Handbook,' *Portsmouth*, 1911, p. 193.

CHAPTER X.

RECENT DEPOSITS.

The movement which caused the sea to retire from the coastal plain of Hampshire and Sussex, and enabled the Combe Rock and Brickearth there to overspread or replace earlier post-Tertiary deposits of marine origin, seems to have continued without important interruption down to the end of the Pleistocene period, by which time the sea-level was relatively lower than at present by at least 50 feet, and not improbably 70 or 80 feet.

The coast-line then lay farther south than now—several miles farther south in the Bracklesham Bay area, where the sea is shallow and much ground has been lost within historic times; while the Isle of Wight, united with the mainland, formed a peninsula of the same type as the so-called "Isle" of Purbeck. The ground at that time occupying the site of Spithead and the Solent doubtless shared the characteristics of the country on either side of the existing strait, and may be pictured as sloping evenly from the north, and with a rolling contour from the south, towards the shallow valley of the "River Solent," which had already lost the upper part of its basin, and may have headed not far westward of Hurst Castle, on the original line of trunk drainage.[1] Contemporary river-deposits lie deep, and the records of borings put down at the forts at Spithead[2] afford but little information concerning them. Drift-wood and a band of "vegetable matter" were found about 50 feet below high-water mark at Horse Sand Fort, and a jaw-bone of red deer about 80 or 90 feet below the same datum at Noman's Fort; but these remains were associated with marine shingle and sand forming parts of banks which may have been accumulated by currents after the opening of the strait. Indeed, the scouring and shoal-building of tidal currents in Recent times have so shaped or modified the bed of the Solent that it now bears only a superficial resemblance to a river-valley: instead of a continuous longitudinal gradient, the Admiralty charts indicate a number of hollows, of which the deeper lie near either end of the strait, and the deepest of all in the Needles Channel, on the west.

About the beginning of the Recent period the elevatory movement was arrested, and, after a pause of uncertain duration, there set in a fairly steady depression, which continued through Neolithic times, and is inferred to have ceased between 3,000 and 4,000 years ago.[3] Though the vertical displacement involved in the latter movement was comparatively small, it entailed some notable

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[1] *See* C. Reid, 'Submerged Forests,' 1913, p. 76.

[2] 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, pp. 169–171, and *Geol. Mag.*, 1865, p. 46.

[3] C. Reid, *ibid.*, p. 115.

changes in the topography of the coastal districts dealt with in this memoir, for, much of the ground there being flat and low-lying, the sea gained upon it quickly as it sank, submergence hastening the progress of erosion along the shores. Results of this subsidence are seen to-day in the drowned and partly aggraded condition of the lower reaches of the river-valleys that open on the coast, and in the occurrence of peat-beds and rooted tree-stumps at various depths below high-water mark. The same movement probably contributed largely to the final detachment of the Isle of Wight from the mainland,[1] and may, indeed, have been the immediate cause of severance, though Mr. Reid[2] is inclined to think that an isthmus existed in the neighbourhood of Hurst Castle and Yarmouth at a time not long anterior to Caesar's invasion, or somewhere between 1,000 and 2,000 years after the subsidence is inferred to have ceased.[3] But, whether the final breach was brought about by subsidence or by coast-erosion, it is certain that the latter process has had much to do with the development of the strait between the Island and the mainland. The Solent has been termed a "submerged river valley," and such in a measure it is, but it is one that has been considerably enlarged by marine agencies; and the same may be said of each of the drowned valleys which form the harbours near Portsmouth.

The Recent deposits shown on the Lymington and Portsmouth Sheets of the Geological Survey Map comprise—*Alluvium*, which includes the marine and estuarine muds exposed between tide-marks on the coast and in the tidal reaches of the rivers, besides the freshwater flood-loams bordering the streams inland; *Peat*, associated with the inland Alluvium; *Shingle*, of existing and former beaches, and *Blown Sand*, in small accumulations overlying the banks of shingle.

Alluvium and Peat.

The principal deposits of surface-peat occur in the north-western part of the Lymington district. Though of small extent, the features to which they give rise are sufficiently marked to have gained distinctive names for the tracts of marshy bottom in which they lie. Wilverley Bog in the valley of the Avon Water, north-west of Sway; Hincheslea Bog, south-west of Brockenhurst, and Crabtree Bog in Rhinefield Walk, may be mentioned as examples. Other deposits, too small to map, occur in the valley of the Dark Water south of Langley, and probably in that of the Mopley Brook, to the east, where there is a tract of marshy ground called Floating Island, south of Sprats Down. Above the valley-bottoms patches of thin peaty soil are common on the Barton Sands near Brockenhurst, and on the gravel of Beaulieu Heath, notably on Hatchet Moor.

The alluvial loams inland seem to be of little interest. They

[1] *See* A. Strahan, 'On the Physical Geology of Purbeck,' *Proc Geol. Assoc.*, vol. xiv, 1896, p. 407.

[2] *Ibid.*, p. 75, and *Brit. Assoc. Report for 1911*, 1912, p. 385.

[3] It is the present writer's impression that the strait was opened at an earlier date.

can be seen in the banks of all the streams: perhaps nowhere to better advantage than in those of the Lymington River about Balmer Lawn, where they contain seams of small stones, and rest on gravel at a depth of 2 to 3 feet below the surface.

Towards the coast the alluvium bordering the streams becomes finer in texture, and in the tidal reaches consists chiefly of blue-grey silty mud, which acquires a rusty tint on lengthy exposure to the air. Near Lymington a broad belt of such mud, crowded in places with *Scrobicularia piperata* Belon., *Cardium edule* Linn., and other shells, forms the foreshore for a distance of seven miles eastward of Hurst Castle. The area of slack water which promotes this accumulation of fine sediment owes its existence largely to the shelter afforded by the shingle-spit of Hurst Castle; the spit itself being due to the sea-ward deflection of the westerly 'long-shore drift at the abrupt change in the trend of the coast[1] near Milford (fig. 1, p. 4). At low tide the visible outer limit of the mud-flat is in some places indefinite, and in others marked by a miniature cliff, denoting erosion. In such yielding material appreciable readjustments in the boundary are likely to occur with every variation in the direction of the wind.

Similar mud-flats exist, in sheltered positions, west of Stone Point, and north-west of Calshot Castle spit at the mouth of Southampton Water.

Continuing eastward, the next considerable spread of alluvium is that on the bed of Portsmouth Harbour. Here extensive excavations made from time to time during the enlargement of the Dockyard have furnished much information, both as to the composition of the Recent deposits, and the nature of the surfaces on which they lie.

The succession observed by Sir Henry James[2] in the sides of the Steam Basin made in 1847 was, briefly, as follows (fig. 13):—

5. Clay, forming the bed of the present estuary.
4. Shingle, marine.
3. Blue clay, 4 feet, similar to the present estuary mud, and containing common shells now found in the harbour.
2. "Forest," with roots of trees *in situ* at a depth of 16½ to 29 feet below high-water mark. "Amongst the peaty matter . . which is 2 feet thick in the same stratum with the trees," James found "*Lacuna montaguei* [*L. puteolus* Turton] . . indicating the presence of very shallow salt water . . . and the growth of *Zostera marina*, on which that mollusc feeds."
1. Fossiliferous London Clay; surface sloping northward and towards the inner part of the harbour.

In 1871, C. J. A. Meyer[3] published a detailed account of phenomena presented in some clear sections, "many hundred feet in length," that were opened at the Dockyard Extension Works

[1] This change marks the point where an older coast-line, whose general trend is indicated by the northern shore of the Solent near Lymington, is intersected by a newer coast-line, resulting from the relatively rapid erosion of Christchurch Bay.

[2] 'On a Section exposed . . . in Portsmouth Dockyard,' *Quart. Journ. Geol. Soc.*, vol. iii, 1847, pp. 249–251.

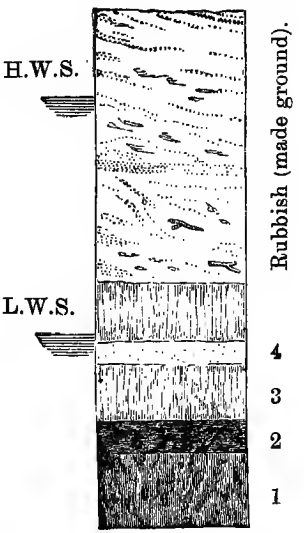
[3] 'On Lower Tertiary Deposits recently exposed at Portsmouth,' *Quart. Journ. Geol. Soc.*, vol. xxvii, 1871, pp. 83, 84.

on the south side of Fountain Lake, about three-quarters of a mile north of the Harbour railway station. In the area covered by the workings the upper surface of the harbour mud is stated to have been from 6 to 7 feet above low-water level, while the under surface sloped north-westward, from a few feet above, to 30 feet below, that datum.

With reference to his diagram section, of which the accompanying fig. 14 is a reproduction, Meyer thinks there is little doubt that the (Plateau)

FIG. 13.—*Vertical section of Recent deposits, Portsmouth* (H. James).

(From *Quart. Jour. Geol. Soc.*, vol. iii, 1847, p. 250.)



1. London Clay. 2. Forest: roots of trees and peat. 3. Blue clay, estuarine. 4. Shingle, marine. 5. Clay, estuarine.
H. and L.W.S. High and low-water, spring tides.

gravel *x*, capping the bank on the left, was once continuous over the harbour area, now occupied by mud or water.

"The older and newer mud-deposits, A and B," he writes, "were probably formed under very similar conditions. The bed A is first seen in the sections at about 300 feet from the low gravel-capped escarpment, and spreads out northward and westward until cut off, as it were, by the deep water along the Fountain Lake. It rests everywhere directly on Eocene sands and clays; and its lower beds are in a great measure made up of these underlying sands and clays re-deposited. This is so much the case, that it is often difficult, even in the open cuttings, to distinguish between the top of the Eocene and the bottom of the mud."

Meyer states that mud-bed A is crowded with recent shells at and near the surface, and usually also near its base; that it contains seams of fine subangular shingle with recent shells, and that antlers of red and fallow deer have been met with in it.

"Change of level," he continues, "or possibly the silting up of some narrow inlet to the tidal water, must at some time have converted this mud

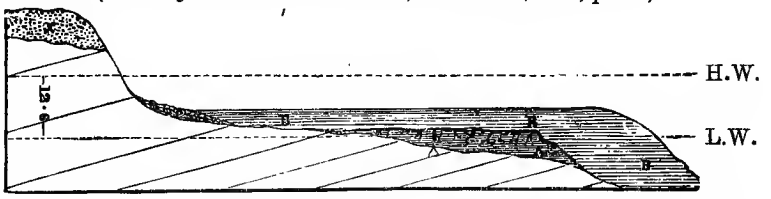
deposit A into a land surface, as its surface, where not eroded, is seen dotted over with the stumps of trees of small growth—possibly alder or willow, their roots often penetrating downwards vertically to a depth of 5 feet. The present surface of this root-bed stands at from 3 feet above to 2 feet beneath the present low-water level of the harbour."

The more recent mud-bed B "commences at the foot of a low escarpment, and, spreading northwards and westwards, rests everywhere directly on the Eocene, or on the mud-bed A where this is present. The surface of the mud B stands at from 6 to 7 feet above low-water level, or just midway between ordinary high and low water. One may suppose, indeed, other conditions remaining the same, that this level would be indefinitely maintained, the flow, and consequently the carrying powers of the water on and off the mud being equal. A study of the sections tends to confirm this idea; for there is evidence in these of very slow deposition near the surface of the mud in most places, and of very rapid deposition in a few others—the rapid deposition, as along the edge of Fountain Lake, being clearly the result of silting up to a certain level.

"The spread or overlap of the mud-bed B so far beyond that of A seems to point to a cutting back of the gravel-capped escarpment, for the same distance, since the submersion of the root-bed."

FIG. 14.—*Section showing the Relative Positions of the Gravel- and Mud-deposits, Portsmouth* (C. J. A. Meyer).

(From *Quart. Journ. Geol. Soc.*, vol. xxviii, 1871, p. 83.)



x. Gravel. A. Old mud-deposit, with stumps and roots of trees.
B. Recent mud-deposits. C. Shingle.
H.W. High-water mark. L.W. Low-water mark.

Lateral erosion of the kind referred to in the last paragraph is still in progress, as will presently be shown, though, owing to the checks imposed by numerous artificial works in Portsmouth Harbour, its effects are much less apparent there than in the adjacent harbours of Langstone and Chichester.

On the western side of Portsmouth Harbour two trial-bores put down by Weevil Lake, Gosport, met with a "peaty earth" resting on "earth with small stones" (possibly an old soil), beneath 55 to 60 feet of "grey marsh clay."[1]

On the coast, weathered Bracklesham clay with tree-roots was noted by the Rev. Osmond Fisher at Lee-on-Solent, "opposite the mouth of a valley" (apparently the slight depression between the pier and the railway station), and a "sunk forest" near the eastern end of Stokes Bay.[2]

A bed of peat with tree-stumps is occasionally laid bare on the foreshore at Southsea, between the Castle and Lumps Fort. At South Parade Pier a boring proved its thickness there to be 7 feet; the underlying deposits met with being, in descending order,—

[1] Undated MS. note, probably by W. Whitaker, in Geological Survey Office, "from specimens communciated by Mr. J. Carruthers of Haslar."

[2] *Quart. Journ. Geol. Soc.*, vol. xviii, 1862, pp. 77, 78.

Gravel, 2 feet; Clay, 4 feet; Shingle, 4 feet; Sand, 6 feet.[1] The peat extends inland beneath New (or East) Southsea, along the channel of an old creek, and has caused settlements in buildings above it. At the junction of Clarendon and Brandon roads, peat and soft mud fill the channel to a depth of 36 feet.[2]

Clay with logs of wood has been observed at the mouth of Chichester Harbour, and on the shore near West Wittering bones of ox occur in a Recent deposit, noticed on an earlier page (57).

Shingle and Blown Sand.

The constituents of the Recent shingle are mainly derived from the Plateau Gravel, the débris of which is constantly delivered to the shore by soil-creep, landslip, and falls of cliff along many miles of coast. With this source of supply so close at hand, it is not surprising to find that a large proportion of the beach-stones are of subangular form, and hardly to be distinguished from the stones of non-marine gravels, but for a certain smoothness and gloss.

In the Lymington district the effects of the westerly shore-drift produced by the prevailing winds are well shown in the shingle-spits of Hurst Castle, Needs Oar, and Calshot Castle; each of which is built out eastward from a salient angle of the coast. In the spits the shingle is usually more rounded than elsewhere.

On the Hurst Castle bank, which rises to about 12 feet above ordinary high-water mark, hook-like prominences called "points," on the leeward side, mark successive positions of the spit-head; and longitudinal ridges or "fulls" indicate lateral accretions formed at high-water during violent gales. Sir Charles Lyell[3] states that "in the great storm of November, 1824, this bank of shingle was moved bodily forward for forty yards towards the north-east; and certain piles which served to mark the boundaries of two manors were found, after the storm, on the opposite side of the bar." Both Hurst and Calshot spits, however, seem to have undergone little change in their general outline for many centuries.[4] They have reached a stage at which direct off-shore growth is checked by cross-currents, and their heads are deflected along the verge of deepwater channels which are kept open, and probably were excavated, by tidal scour. At ebb tide a strong current sets out of the Solent through the Needles Channel south and south-west of Hurst Castle. It is inferred that much of the coarse waste from the cliffs of Christchurch Bay, carried eastward by shore-drift, is caught by this current at the head of Hurst Castle spit, and thrown out of the Needles Channel westward, to form the extensive shoals and small whale-backed island of The Shingles (fig. 15), north of Totland Bay.

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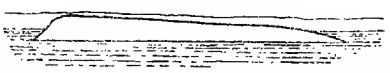
[1] 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, p. 175.
[2] From a note by C. E. Hawkins, in Geol. Survey Office.
[3] 'Principles of Geology,' 4th ed., 1835, vol. ii, p. 45.
[4] *See* J. B. Redman, 'On the Alluvial Formations, and the Local Changes, of the South Coast of England,' *Proc. Inst. Civil Engineers*, vol. xi, 1852, pp. 191–193.

Along the coast near Portsmouth the shingle forms an almost continuous belt, mostly of small width, but expanding to between one-third and one-half of a mile at either end of Stokes Bay, at Southsea, and at Sinah Common on Hayling Island. The shingle at Sinah Common is arranged in well-marked "fulls," which in places enclose small lagoons. At the western end of the Common it is covered by low dunes of fine sand blown up from the East Winner bank hard by.

In the Portsmouth district the westerly shore-drift is modified by local currents—notably the out-draught from the harbours—and its influence on the coastal topography is less apparent than in the area of the Lymington map-sheet. The only well-marked spits (as distinct from the shoals so-named, not shown on the 1-inch map) are of small size, and lie in the mouths of the harbours, with their hooked points away from the coast, showing that the direction of their growth is largely conditioned by the in-draught at flood tide. The outflow from the harbours gives rise to external shoals of sand and shingle, which splay-out delta-wise from the harbour-mouths. At Blockhouse Fort, on the spit forming the western bank of the entrance to Portsmouth Harbour, a boring proved 70 feet of shingle and sand with oyster-shells,

FIG. 15.—*Island on The Shingles, near Hurst Castle, looking north-west.*



above the Bracklesham Beds. This seems to be the greatest thickness of Recent shore-deposits recorded in the mainland area of Sheets 330-331. Off the coast, 90 feet of the same kinds of sediment were traversed in the well at Noman's Fort.[1]

Around the harbours strips of subangular shingle—often well-worn and assorted—form small beaches separating the inner flats of alluvial mud from the enclosing banks of loam and gravel. In Langstone and Chichester Harbours, particularly, the banks, whence the shingle is clearly derived, are in many places true cliffs, bearing all the marks of erosion by waves, and displaying in plan the characteristic curves of a sea shore. As might be inferred from their outlines on the map, it is the eastern banks, facing the prevailing wind, that are wasting most quickly. The banks on the western side are more often shelving, and their indentations, which usually form the mouths of silted creeks, differ from the gently curved embayments of those parts of the shore where erosion is, or lately has been, making better progress.

At present, abrasion is proceeding most rapidly at the southern end of Thorney, west of Longmere Point, where, according to an estimate made by the writer, the average rate of recession of the low cliffs of gravel and London Clay, during the last 23 years, has been about one yard per annum. The cliffs there are bitten into

[1] 'Water Supply of Hampshire,' *Mem. Geol. Surv.*, 1910, pp. 85, 170.

little coves and stacks; and the shore below is strewn with fallen turves and bushes, together with tile-drains from the soil. These and other indications of wastage are to be seen elsewhere, in many places.

North-east of Fleet, on Hayling Island, vertical bands of vitrified Reading clay in the harbour-bank mark the position of an old kiln-pit which, when in use, must have been out of reach of the water that now washes its remains at high tide. Even in spots which appear, from the map, to be well sheltered one occasionally finds evidences of recent slow erosion; perhaps in the middle of a stretch of shore where, owing to the accumulation of silt, the land on the whole has been lately gaining upon the water. The western side of Thorney affords an instance. South of West Thorney the banks are being sapped by wavelets, but at a rate so deliberate that some live elms, which have been undermined in the process, have adapted themselves to the changing conditions, and while remaining erect, have settled down upon the beach, where they are sustained by arches of thickened root connecting them with dry land.

It has been said of the harbours near Portsmouth, that "sea and waves do not erode enclosed basins such as these,"[1] but, having regard to the phenomena presented on their shores, it seems impossible to doubt that wave-action has really played an important part in their development.

[1] C. Reid, 'Submerged Forests,' 1913, p. 76.

CHAPTER XI.

ECONOMIC GEOLOGY.

Soils.

The "solid" edition of Sheets 330 and 331 of the Geological Survey Map would be of little service as an index to the character of the local soils, for these are mostly of the "transported" class, and result from the weathering of superficial formations which often have little in common with the country rock they overlie.

About Portsmouth the Cretaceous and Eocene beds are almost completely masked by spreads of brickearth and gravel: the Chalk has no soil of its own; the moist and heavy clay-land characteristic of the Reading Beds is confined to small tracts of rough meadow near Great Salterns and West Itchenor; while the London Clay, Bagshot Sand, and Bracklesham Beds contribute between them only two or three square miles of light to medium loam, about Rowner and Alverstoke.

The Barton Beds of Rhinefield and Wilverley bear the poorest sort of soil; thin, lacking in staple, and capable of supporting little but heather and bed-furze. The strong loams yielded by the Headon Beds lie, as a rule, on pronounced slopes along the sides of the valleys, and are mostly occupied by grass and timber.

Over the greater part of the area mapped as Plateau Gravel the soil consists of light stony loam, which doubtless includes the relics of a former covering of Brickearth. It needs but a foot of this loam to render the gravelly grounds cultivable, and its absence or presence makes all the difference between lean moorland pasturage, fit only for the "heath-croppers," such as that on Setley Plain and Beaulieu Heath; and moderately fertile grass- and arable-land, like that around Hordle, Norleywood, Exbury, and Stubbington.

The firm, well-knit loams of the Brickearth make excellent soils, especially on a permeable foundation. Over clays, the Brickearth lands are apt to be heavy, and sub-soil drainage has often to be undertaken, as, for example, on the Lower Eocene Beds in the eastern part of the Portsmouth district. There are tracts of exceptionally strong clay-loam on the Brickearth about Tye on Hayling Island, and to the south of West Itchenor. The drier parts of the inland Alluvium afford strips of meadow and rough pasture.

Land-dressing.—In bygone times the marls of the Headon Beds were extensively dug for manuring the gravelly and sandy grounds in the New Forest. Two kinds of marl was distinguished: the unweathered "shell-marl" or "malm," containing a large proportion of unbroken shells, and the weathered "cherry marl"—so called on account of a bright-red mottling, due to iron peroxide—in which the shells are mostly comminuted and mixed with their clayey ground mass. The latter appears to have been

used on the lighter sorts of soil. It was said to retain its virtue longer than the shell-marl, but to be slower in producing an effect. The effect produced, however, was not always satisfactory: J. Trimmer[1] mentions, for example, a white marl from the brickyard at Pitts Deep which discoloured wheat grown on land to which it had been applied; and he alludes to the "balling" tendency of the Forest marls generally when ploughed into coarse sands. As dressing, the marls are inferior to chalk, which was for a long time used in their place, but has latterly been superseded in its turn by artificial manures.

In the north-eastern part of the Portsmouth district the rotted upper layers of the Chalk have been worked for marling the overlying Brickearth. The local pits are now overgrown or ponded, but marling is still occasionally done on other parts of the Brickearth flats, beyond the limits of this district. In 1914 the writer noticed an unusually heavy dressing being applied to loam over the Chalk between West Thorney and Emsworth.

Building Material.

Stone.—Although there are no stone-quarries in the area under consideration, a good deal of loose material that comes under this sub-heading is utilised for building purposes. Walls and small dwellings constructed of flint-cobbles from the beach are common on the low-lying parts of the coast. To the east of Portsmouth these are often supplemented by sarsens and foreign erratics from the same source, or from the Pleistocene gravels. The walls of the parish church at South Hayling are largely composed of such materials, and tabular boulders of sandstone are included in the lower courses of masonry in other old buildings in the neighbourhood. Slabs of ferruginous shell-rock from the Barton Clay, hardened by exposure on the shore, have been used for building in the western part of the Lymington district; also blocks of the iron-cemented gravel known as "Burley Rock," examples of which can be seen in the walls of the churches at Boldre and Brockenhurst.

Cement has been manufactured in small quantities from the septaria of the Barton Clay.[2] Gravel suitable for concrete and rough-cast occurs within easy reach of every village westward of Portsmouth; it is the chief constituent of the Peterson Tower at Sway, which dominates the south-western part of the New Forest. The sands of the Upper Barton Beds are dug for building and other requirements on the heaths west and south-west of Brockenhurst; also on either side of the river at Lymington.

Bricks, &c.—In the neighbourhood of Portsmouth the clays of the Reading Beds are used in the making of bricks, tiles, chimney-pots, &c., near Great Salterns, and were formerly worked for the same purposes on the north bank of Chichester Channel near West Itchenor. Bricks for use in the Dockyard and in forts west of

[1] *Journ. Roy. Agric. Soc.*, vol. xvi, 1855, p. 133.

[2] Mr. Ll. Treacher states that septaria for this purpose were being gathered on the shore near Barton, and carried by boat to Keyhaven, about 40 years ago.

Portsmouth have been made in temporary yards opened on the spot. In this part of the country the Bracklesham Beds seem not to have been exploited for building material. The main source of brick-loam is the Brickearth formation, which has been dug in a large number of pits scattered over the levels between Stubbington and East Wittering. At the present time the chief seat of the brick-making industry is the eastern part of Portsea Island, around Copnor and Milton. Here the brickearth thinly coating the Eocene Beds and Plateau Gravel is skinned off in shallow workings, which are speedily covered by streets of small dwellings—building and brick-making being carried on side by side. The loam is often eked out by the lavish use of cinders, broken crockery, and other refuse, with detriment to the appearance of the bricks.

Near Lymington the Brickearth has been worked to the south and east of Milton; but the raw materials most freely employed are the loams and clays of the Headon Beds, which as a rule yield bricks of a good, bright-red tint. There are yards in these beds at Hordle, Brockenhurst, Royden, Lymington, Pitts Deep, Exbury, and Langley: almost all, however, are now disused, owing to their inability to compete with larger factories at a distance.

Dob.—Cottages, barns, and enclosure-walls made of sun-dried earth are common in the older settlements near Lymington, especially to the west of that town. The mud or "dob" used in their construction consists of puddled stony loam, with or without bonding of straw or rushes, and usually white-washed or plastered, but not seldom left bare on the weather side.

About Portsmouth the mottled "Stamshaw" clay of the Reading Beds is used for puddling dams and caissons.

Road Metal.

The only material suitable for road-mending is got from the gravels, which are dug for this purpose in most of the localities where they occur within easy reach of the surface. Beach-shingle is frequently put down on paths and lanes near the coast. Shingle for ballast is taken by small vessels from the Shingles Bank, off Hurst Castle.

Iron-ore and Fuel.

Lumps of concretionary iron-stone from the Lower Headon Beds used to be gathered on the shore near Hordle, for smelting at the ironworks which stood by the dam at Sowley Pond.

A local industry more likely to be revived in the near future is that of peat-digging; formerly carried on in some of the bogs near Brockenhurst, *e.g.*, in the valley of the Ober Water.

Water.

The water supply of Hampshire and Sussex as a whole has been described in separate memoirs.[1] The supplies in the area now

[1] 'The Water Supply of Hampshire,' by W. Whitaker and others, *Mem. Geol. Surv.*, 1910; 'The Water Supply of Sussex' (1899), by W. Whitaker and C. Reid; Supplement (1911) by W. Whitaker.

dealt with are generally procured from local sources, except in the case of Portsea Island and the neighbourhood of Gosport, which are largely served by wells and impounded springs situated in the Fareham district (Map-sheet 316), to the north. Almost all the geological formations which appear at the surface yield water, though the more clayey divisions, as might be anticipated, are normally less productive than the rest. Dipping approximately southward with the prevailing inclination of the ground, the solid strata transmit to this belt of coast-country a large proportion of the rain absorbed by them in the higher grounds farther inland; while the superficial beds, thanks to their wide extent, also make a substantial contribution to the general supply, though, owing to their mode of occurrence, they are more strictly dependent upon local precipitation for their replenishment.

The average annual rainfall varies from about 25 inches on the low ground near Portsmouth to about 33 inches on the gravel-capped plateaux around Beaulieu and Brockenhurst.

The *Chalk* can be relied upon to furnish good supplies near its outcrop north-east of Portsmouth, but to the south, where it falls much below sea-level, and is covered by a considerable thickness of Eocene strata, the yield obtained from it in borings sometimes proves unsatisfactory. With an increase in depth and in distance from gathering-ground, the joint-fissures which serve as the principal ducts diminish in size and number, thus reducing the chances in favour of successful exploitation by boring. On Hayling Island, out of four wells recorded in the "Water Supply of Hampshire"[1] as having been bored into the Chalk beneath an Eocene cover, two obtained little or no water from that formation, though both penetrated to depths of more than 170 feet below the base of the Reading Beds. Similar failures are recorded from Portsea Island, but the majority of the wells carried below the Eocene Beds there, and about Gosport, obtain fairly good supplies from the Chalk; the water in some cases rising to the top of the bore-hole from depths of several hundreds of feet.

The *Reading Beds* hold some water in their sands, but these are usually too thin and inconstant to be worth sounding for, and it is probable that most of the wells which enter this formation are carried through to the Chalk.

The *London Clay*, owing to its numerous sandy inclusions, yields moderate supplies from several horizons, but chiefly from the Basement-bed, in which the water is held up by the Reading clays below. Where the texture of the London Clay is such as to allow of a free circulation, the water is of good quality. Where, on the contrary, the flow is sluggish, the water is often chalybeate, owing to concentration of the iron salts so prevalent in this formation.

The *Bagshot Sands* rank high as a water-bearing terrane around Gosport, but yield little to the east, where their thickness and catchment-area both become reduced.

Fair supplies are got from the sands of the *Bracklesham Beds*.

[1] *Mem. Geol. Surv.*, 1910, pp. 96, 97.

Here, however, even more than in the London Clay, the smaller springs are apt to possess a disagreeably ferruginous flavour. From sandy beds, probably of Bracklesham age, a strong artesian flow, with a head of 2 feet, was obtained from a boring at the Lymington Water Works, at Ampress, north of the town,[1] Noman's and Horse Sand Forts at Spithead are supplied from this formation by means of borings in the sea bed. In the Noman's well the water rose to within a footof high-water mark of ordinary spring tides.[2]

It may be noted here that the level of the water in some of the wells around Portsmouth Harbour is affected by the tides, and over-pumping has occasionally resulted in a salt or brackish indraught from the sea, through permeable strata of various ages. The Water-supply Memoir referred to above contains an interesting account of the contamination of the Gosport Water-works well at Foxbury (near Lower Bridgemary), where sea-water was drawn into the 'cone of depletion' through fissures in the Chalk.[3]

The *Barton Clay* doubtless holds some water in its more arenaceous divisions. As far as the writer is aware, no supplies are obtained from it in the area covered by this memoir.

With their high degree of permeability, wide outcrop to the north, and retentive foundation, the *Barton Sands* are well qualified to serve as a natural reservoir, and they actually form, if not the chief, at least the most reliable, source of water in the country around Lymington. Numerous springs break out along the boundary of the Headon Beds in the valleys south-west of Brockenhurst, and in the area of the Barton Sands inlier about Lymington, where the copious source at Ampress has been used, in conjunction with artesian water, for supplying the town. Other springs run from beds near the junction with the Barton Clay in the lower part of the bluff facing Southampton Water at Ashlett, near Fawley. Water is also obtained from this formation in a number of bored wells put down through the Headon Beds, the results in some cases demonstrating the existence of artesian or sub-artesian conditions. In a trial-boring at Keyhaven, for example, water, apparently from the base of the Barton Sands, rose $2\frac{1}{2}$ feet above the surface of the ground.[4]

Concerning the water-bearing properties of the *Headon Beds* but little information is available. Water may be seen trickling from their sandy members in sections on the coast and inland, but it is probable that the supplies obtained from them are small, and that many of the wells which end in this formation serve as sumps for water circulating in the overlying superficial deposits. It is noteworthy, however, that at a spot about half a mile north of Sway Station some water was got from the Headon Beds in a well which failed to obtain any from the Barton Sands below.[5] The Sands appear not to have been bottomed, but, apart from

[1] 'Water Supply of Hampshire,' p. 105.
[2] *Ibid.*, pp. 169, 171.
[3] *Ibid.*, pp. 48–50.
[4] *Ibid.*, p. 174.
[5] *Ibid.*, p. 139.

this, the position of the well—on a ridge which approximately coincides with a water-parting and an anticlinal axis—strikes one as being decidedly unfavourable.

The *Plateau Gravel* is among the most important of the water-bearing formations. Springs abound on the margins of the plateaux, and tend to increase in volume towards the coast, where copious out-pourings may often be seen, racing through the shingle from the foot of a low gravel-bluff, as at Pitts Deep and Lee-on-Solent, or falling in cascades from a cliff, as at Barton. In the Lymington district water for farm and domestic use is drawn from surface-springs and shallow wells wherever the gravel occurs in bulk.

Small supplies are got from the *Brickearth* and associated deposits in the levels east of Portsmouth. As much of the Brick-earth here is but slightly permeable, watery ditches are a common feature of the country where it forms the sub-soil; and the springs that issue from its base on the shores of the harbours are mostly of a feeble kind.

The numerous *Ponds* which contribute so much to the charm of the southern parts of the New Forest are artificial features, formed as a rule by the damming of well-marked brooks, with the object of providing decoys, fish-stews, or water-power for mills.

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